



NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

**REDUCING CYCLE TIME AND INCREASING VALUE
THROUGH THE APPLICATION OF KNOWLEDGE
VALUE ADDED METHODOLOGY TO THE U.S. NAVY
SHIPYARD PLANNING PROCESS**

by

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December 2005

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE December 2005	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE: Reducing Cycle Time and Increasing Value through the Application of Knowledge Value Added Methodology to the U.S. Navy Shipyard Planning Process			5. FUNDING NUMBERS	
6. AUTHOR(S) Christine L. Komoroski				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (maximum 200 words) <p>As technology advances at an ever-quickenning pace, it has become more important to identify ways to capture and measure the spectrum of benefits information technology resources can provide. In today's competitive global economy, organizations that best employ and manage knowledge assets to maximize process executions, and improve process outputs, will prosper. Through the analytic form of analysis known as the Knowledge Value Added (KVA) methodology, this thesis will identify a technique to measure the performance of knowledge assets. The resulting values can be compared in varying notional scenarios to assess potential improvements for knowledge-intensive processes. This method of analysis will demonstrate how reengineered processes enable organizations to reduce costs, and maximize knowledge creation and production capacity.</p> <p>A Proof of Concept was developed to analyze the long-established Shipyard planning yard processes, which supports maintenance and modernization of the U.S. Navy Fleet. With these baseline processes as the cornerstone for academic analysis, the KVA methodology shows iterations of varying scenarios using automated data capture and collaborative technology, and the return each provides. Most importantly, the methodology establishes evidence which suggests reengineered shipyard planning yard processes will shorten the duration of Navy ship availabilities, while reducing the <i>annual</i> operating cost of four government planning yards by more than \$30 million dollars.</p>				
14. SUBJECT TERMS Knowledge Value Added, KVA, Ship Maintenance and Modernization, Return on Investment, ROI, Return on Knowledge, ROK, Information Technology, IT, Laser Scanners, Collaboration, Planning Yards, Navy Shipyards			15. NUMBER OF PAGES 87	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	

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APPLICATION OF KNOWLEDGE VALUE ADDED METHODOLOGY TO THE
U.S. NAVY SHIPYARD PLANNING PROCESS**

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

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ABSTRACT

As technology advances at an ever-quicken pace, it has become more important to identify ways to capture and measure the spectrum of benefits information technology resources can provide. In today's competitive global economy, organizations that best employ and manage knowledge assets to maximize process executions, and improve process outputs, will prosper. Through the analytic form of analysis known as the Knowledge Value Added (KVA) methodology, this thesis will identify a technique to measure the performance of knowledge assets. The resulting values can be compared in varying notional scenarios to assess potential improvements for knowledge-intensive processes. This method of analysis will demonstrate how reengineered processes enable organizations to reduce costs, and maximize knowledge creation and production capacity.

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LIST OF ACRONYMS

ALT	Actual Learning Time
CO	Commanding Officer
COTS	Commercial Off the Shelf
COP	Configuration Overhaul Planning
DBMS	Database Management System
DoD	Department of Defense
DoN	Department of the Navy
DSA	Design Services Allocation
DTM	Design Tasking Memorandum
EA	Evolutionary Acquisition
FMP	Fleet Maintenance Plan
GUI	Graphical User Interface
GWOT	Global War on Terrorism
IT	Information Technology
ITMRA	Information Technology Management and Results Act
JIS	Job Information Sheet
KVA	Knowledge Value Added
LAR	Liaison Action Request
NDE-NM	Navy Data Environment—Navy Modernization
NSRP	National Shipyard Research Program
PLM	Production Line Manager
POC	Proof of Concept
POM	Program Objectives Memorandum
PM	Project Manager
ROK	Return on Knowledge
ROKI	Return on Knowledge Investment
ROI	Return on Investment
RLT	Relative Learning Time

SAR	Ship Alteration Request
SCD	Ship Change Document
SHIPALT	Ship Alteration
SID	Ship Installation Drawing
SME	Subject Matter Expert
SSR	Ship Service Request
S&T	Science and Technology
TLT	Total Learning Time
2D	2-Dimensional
3D	3-Dimensional

ACKNOWLEDGMENTS

I would like to thank Dr. Tom Housel, for introducing the idea for this research to me, and for trusting that I would create a thesis of value and importance. Exploring Dr. Housel's world of knowledge theory was a new experience, and one I have grown to appreciate. Many thanks also go to Professor Glenn Cook for your guidance and help.

There are many Subject Matter Experts who spent countless hours corresponding with me in person, by telephone and by email. Their collective knowledge, experience, and expertise were invaluable to this research, and I could not have done it without the help of each professional. To start, thanks goes to Spatial Integrated Systems (SIS) representatives Tom Long and Brian Tilton, and UGS representative Matt Brennan. All were extremely helpful in providing resources, documents, and information when needed. It was a pleasure working with all vendor representatives on this research project.

Time spent with Subject Matter Experts was critical to the success and reliability of this research. Many thanks go to Puget Sound Planning Yard representatives Jim McGonigle, Donald Cosner, Sam Doubleday, John Keene, and Dave Blair, who willingly spent their valuable time discussing their trade and sharing their experiences. The information provided from these individuals was critical to establishing a starting point and understanding the purpose and goals of Planning Yards. Similarly, Terry Dolan of UII deserves many thanks for going above and beyond to improve my understanding of the planning yards, and for the help he provided in confirming KVA-related estimates.

To Eduardo Castro, of GaussSoft Software, and Professor Buddy Barreto, thank you for your time and helpful thoughts on my KVA analysis. Your insight and attention to detail were helpful in perfecting the Proof of Concept.

Finally, love and thanks to my husband, Tom, for the support, understanding, and motivation he provided throughout the writing of this thesis.

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I. INTRODUCTION

A. BACKGROUND

All organizations operate in an environment of competition and limited resources. The most successful organizations are typically those prepared to maximize intelligent use of available resources. With strategies based on a guiding vision, successful organizations have policies in place to remain current and competitive despite the constantly evolving technological environment. The Department of Defense (DoD) is not an exception to these organizational generalizations. Within the constraints of the defense budget, the wide range of military operational commitments, and an intricate acquisition process, defense leaders have an inherent responsibility to properly maintain and modernize the United States Armed Forces to retain the competitive advantage, and widen the gap to maintain technological superiority in an unpredictable world.

The DoD spends more than \$59 billion per year on a broad range of defense maintenance capabilities and programs. With a current inventory of approximately 300 ships, 15,000 aircraft, 900 strategic missiles, and 330,000 ground vehicles, the need for maintenance programs is evident. (DoD Maintenance Policy, 2004) Navy Fleet maintenance and modernization efforts for fiscal year 2005 amounted to 85 ship and submarine scheduled availabilities—that is, the assignment of a ship to an industrial activity to accomplish repairs, maintenance, or modernization tasks—at a cost of \$3.9 billion. (Hugel, 2005) Given this relatively high cost of maintenance activities and relative ease at which those activities are funded, it may be concluded that the nation's leaders are committed to maintaining force operational readiness, superior technological edge, and quality material condition of assets.

Of any service, the Navy must be extremely diligent in its maintenance efforts. Ships and submarines provide great value to national defense objectives; however, the environment, tempo, and duration of typical naval deployments increase the need for proper maintenance and modernization. The Maintenance Policy for U.S. Navy Ships delineates maintenance and modernizations efforts as those aimed “to define and manage the material condition requirements and the configuration of Navy ships.” As such,

maintenance and modernization policy is carefully designed to keep Navy ships operating at the maximum level of material readiness possible. (OPNAVINST 4700.7K) This need is carefully balanced with the reasonable expectation of asset availability to Fleet Commanders, since naval vessels undergoing repair, maintenance, or modernization in an industrial activity facility are unavailable for operational tasking until scheduled work is complete. Although availability periods can range in duration, traditional restricted availability periods last six months.

B. PURPOSE

This research will address the conjectural benefits resulting from the integration of new information technology (IT) assets into existing Navy shipyard design processes, with focus on the work and output generated at the public-sector Planning Yard facilities. Executing many knowledge-intensive, inherently complex, yet technologically outdated design processes, the concept of the Naval planning yard could benefit with a new, IT-based infrastructure. The modern concept of knowledge management will be addressed, and a knowledge-based methodology will be employed to complete an analytic representation of the potential return-on-investment provided by the IT asset, expressed in terms of cost savings, return on knowledge, and return on IT. From the results of this analysis, possible benefits to the DoD and U.S. Navy will be inferred.

As a Proof of Concept, the processes executed at Puget Sound Planning Yard, located in Bremerton, Washington, will be explored. The current, “as is” process will be reevaluated in reengineered notional scenarios incorporating Commercial-off-the-shelf (COTS) technology, including 3-dimensional (3D) laser scanners, a proprietary approach to digital imaging created by Spatial Integrated Systems (SIS), and a collaborative environment technology marketed by UGS Corporation. The Knowledge Value-Added (KVA) methodology will be utilized to compare the “as-is” environment against notional environments that represent maximum use of the new IT resources, with the data applicable to Puget Sound Planning Yard aggregated to represent the four existing public-sector planning yard facilities. Finally, justifications for or against these technologies, based on KVA analysis results and other applicable research, will be provided as recommendations to the Navy. Potential uses for 3D digital modeling and collaborative

technologies in domains outside of the maintenance and modernization realm of activities will be considered.

C. RESEARCH OBJECTIVES

The objective of this research is to analyze the potential benefits investment in data-capturing and collaboration-based information technology could provide in public sector organizations, where “profits” are never part of the return on investment equation. Instead, this research will attempt to find benefits in terms of cost savings, increased process capacity and productivity, and reduced cycle time for the Naval Fleet. This analysis will apply a return on investment methodology capable of demonstrating these advantages in common units of measurement.

Application of this model will provide important insight into the value-adding performance of knowledge assets in a public-sector organization and its defined processes. The analytical approach used, with knowledge theory in its roots, will help identify ways process capacity within public sector organizations may be improved by increasing the value of organizational knowledge assets, both human and IT-based. The information that results from this analysis can be used to make educated and less risky acquisition decisions. Furthermore, it can be used to explore the potential benefits derived from the introduction of IT assets, along with improved engineering into many different processes, across a wide range of organizations.

D. RESEARCH QUESTIONS

Any new IT introduced into modern organization processes always carries a certain degree of risk, as its benefits cannot always be accurately predicted. Through use of the KVA methodology, a decision support model will highlight quantitative evidence based on measurable data and analytical criteria, and demonstrate the impact of IT systems, specifically 3-dimensional terrestrial laser scanners and collaborative environment technologies, in the planning yard processes. Proponents of laser scanners and collaborative environments purport that their technology frees resources, reduces time, improves process efficiencies, and empowers professionals in a variety of ways.

The subject in question, then, is whether acquisition and use of laser scanners and collaborative environments in planning and execution of ship maintenance might 1) decrease cycle time for U.S. Navy ships by minimizing downtime in shipyards, 2) lessen maintenance cost by eliminating or reducing DOD planning yard labor costs, 3) over time, allow the nation's leaders to revise force planning through reduced cycle time, and 4) improve productivity in current planning yard ship check processes to a degree which would allow for greater shipboard modernization. Finally, information technology improvements, particularly the effective capture and storage of ship-specific data, along with the introduction of collaboration and data-sharing, could greatly contribute to the productivity of Navy organizations outside of the planning yard, including all downstream processes, particularly the public and private-sector shipyards which perform the maintenance, modernization, and repair work on Navy vessels.

E. METHODOLOGY

This thesis will attempt to model the current DoD planning yard core processes, and predict as accurately as possible a reengineered process model which incorporates recently developed information technology applications. The Knowledge Value Added methodology will be applied within the Proof of Concept (POC) case study to measure the impact that an introduction of 3D modeling and collaborative technology will have on the current process model. First, all major inputs, processes, and respective outputs will be identified by means of an interview process with planning yard Subject Matter Experts (SME). This analysis will include a cost estimate based on the salary of personnel involved in each process. The subprocess analysis will include planning yard estimates for the "time to learn" each process, the number of personnel involved, and the number of times each process is executed. Market comparable values will be used to help estimate cost figures and add value to the methodology.

To ensure all estimates are reliable, Subject Matter Experts will be asked to rank order the processes in order of complexity, and a correlation will be calculated. A high correlation value ensures quality estimates. The time-to-learn, otherwise described as the knowledge embedded in each subprocess, either embedded in the technology or within the personnel, will be multiplied by the number of executions of that subprocess. The

resulting figure will be used as a basis for the KVA approach for allocating revenue at the subprocess level. For “to-be” and “radical-to-be” models, subject matter experts in the areas of laser scanning, digital imaging, modeling, AUTOCAD, and collaborative technology applications will be consulted, and their resources will be tapped extensively to ensure reliable estimates. Comparing the end values can assist decision makers in determining the ROI benefits of new IT into the planning yard process.

F. SCOPE

“Maintenance and Modernization” is a very broad concept, with a myriad of interrelating concepts, instructions, policies, and specializations for study. In a perfect world, this research would address all areas of the shipyard industry and its stakeholders, from shipbuilding, to maintenance and modernization, and repair. Certainly, the IT assets considered in this research, and information management could benefit each of these specific areas. However, the scope of this research is limited to a relatively narrow field: the Planning Yard industry, and the shipcheck process it conducts for maintenance and modernization efforts. To be even more specific, shipchecks are conducted on Navy vessels for four fundamental purposes: alteration design, material assessment, alteration planning, and repair planning. This research will not cover any specifics of repair planning or material assessment shipchecks, nor will it reach beyond the planning phase into the realm of production. It is hoped that the reader will bear in mind that any benefits or return on investment demonstrated in this thesis only begins to uncover the potential of IT in the much larger shipyard industry.

G. ORGANIZATION OF THESIS

This thesis research will be organized in the following manner:

Chapter I will include an overview of this research project, and will identify the primary objectives and questions of focus. The methodology used to reach conclusions and make recommendations is described. Chapter II contains a literature review of the topics necessary to understand the Puget Sound Planning Yard Proof of Concept case study, found in Chapter IV. The topics covered by the literature review include current Navy Shipyard initiatives, Defense Acquisition, principles of knowledge management,

Real Options Analysis, and information on terrestrial laser scanners and collaborative technology. Chapter III discusses the Knowledge Value Added (KVA) methodology in great detail, to enhance the reader's understanding of the knowledge-based return on investment methodology applied in this thesis to draw conclusions. Finally, Chapter V will summarize the research efforts, state conclusions, and make recommendations to the Navy and Department of Defense.

II. LITERATURE REVIEW

A. CURRENT NAVY SHIPYARD INITIATIVES

America's naval shipyards went through a major transformation during the 1990s, declining from eight public shipyards and more than 70,000 employees to the current size of four shipyards and 23,500 employees. (Klemm, 2002) Despite this reduction, maintenance capability remains intact, as many tasks are outsourced to private industry. For the four remaining public shipyards, significant effort is being put towards standardization and improvement of operations across the board, evident in the SHIPMAIN initiative, the inception of SHAPEC¹, and in the various updates and iterations of the long-standing Fleet Modernization Plan (FMP). The current focus in the shipyard industry and all pertinent policies is find methods to streamline ship availability processes, regularize procedures, and improve maintenance and modernization activities.

1. Fleet Modernization Plan

The purpose of the FMP as written in the document is to outline the process for the “identification, approval, development, funding, and execution of characteristic changes to the U.S. Navy ships and service craft, ensuring installation of a Certified Battle Force Configuration.” Theoretically, FMP doctrine enables the Navy to maintain up-to-date configuration control of its assets, and prevents unexpected ship alterations, interferences and costs. In practice, the effectiveness of Navy configuration control might be contested. Several distinct processes are outlined in the FMP, including ship alteration (SHIPALT) development, FMP Program Development, Program Objectives Memorandum (POM), Budget Development, and Program Execution. The FMP was recently revised, and its 2005 Strategic Plan’s primary mission is to “provide a disciplined process to deliver operational and technical modifications to the FLEET in the most operationally effective and cost efficient way.” (FMP, 2005) The Strategic Plan further defines a standard methodology to plan, budget, engineer, and install

¹ SHAPEC is the Ship Availability Planning and Engineering Center, a Naval Sea Systems Command (NAVSEA) with the goal of standardizing practices and procedures to accomplish ship work by: 1) Determine technical planning and material requirements, 2) development of reusable planning products, and 3) establishment of a data warehouse of planning products. Retrieved Fall, 2005, from <http://www.shapec.spear.navy.mil>

technologically current and affordable shipboard improvements. The overarching goals contained in the FMP Plan, in allowing for ship improvements is to:

1. Maintain a war-ready fleet
2. Correct safety concerns or equipment deficiencies
3. Maximize ship maintenance and reliability
4. Reduce the burden of work on ship's force

The process contained within the FMP most pertinent to this research is the SHIPALT. In the context of Naval shipyards, an alteration is considered any change in a ship's hull, machinery, equipment, or fittings, which involves a change in design, materials, number, location, or relationship of any assembly's component parts. This includes changes that are separate from, incidental to, or in conjunction with repairs. (ISR Glossary, 2005)

2. SHIPMAIN

A family of maintenance initiatives, SHIPMAIN was launched in the fall of 2002 to address the existing culture problems at Navy shipyards. It remains a current policy; its tenants are works in progress. Initiated by former Chief of Naval Operations (CNO), Admiral Vern Clark, SHIPMAIN lays out the framework to ensure that Navy shipyards are transformed to best accomplish the maintenance and modernization tasks required to keep U.S. Naval forces technologically superior. The goal of SHIPMAIN is to ensure all shipyard processes are redesigned, with consistency among different maintenance facilities, to preserve ship quality and lifespan within schedule constraints. Navy leadership believes the SHIPMAIN incentive will ultimately reduce the overall cost of ship maintenance and modernization by installing a common planning process for surface ship alterations. By installing a disciplined management process with objective measurements, SHIPMAIN strives to increase the efficiency of the process without compromising its effectiveness. Finally, the initiative will institutionalize the process, and implement a continuous improvement method. (Balisle & Lafleur, 2003) The overarching concept behind SHIPMAIN is "one shipyard," and its tenants are currently either in place, in process of being implemented, or in the planning phase.

One of the biggest changes introduced by SHIPMAIN applicable to this research is the concept of the Ship Change Document (SCD). Considered a consolidated version

of former SHIPALT documents, the SCD is now the input resource for a web-enabled database called the Navy Data Environment—Navy Modernization (NDE-NM). With full automation of NDE-NM released in June 2005, its utilization was, and continues to be a major change in ship modernization processes. For example, use of a web-enabled database supersedes many FMP requirements. It collapses a broad range of alteration types into two (Fleet and Program), consolidates several modernization practices, processes, and supporting documents, and provides a simple decision making process for modernizing naval vessels. Decision boards are in place to adjudicate an estimated 75 percent of proposed ship changes and all Fleet Alterations. In this process, the authoritative document for each proposed change is the SCD, and it supersedes documents required in the FMP. The SCD is updated at each decision point, and includes technical, cost, and mission criticality information. Approval of a proposed ship change is based on a variety of factors, including a measure of how much benefit the proposed change would provide the Fleet. It is hoped that increased review of ship change proposals will minimize unnecessary costs. (Tate, 2005)

B. DEFENSE ACQUISITION

The federal government spends an estimated \$60 billion each year on IT products and services. While this figure seems high, it is not surprising, as IT is integrated into nearly every government process. Given the rapid pace with which technology is evolving, it is vital that federal acquisitions focus on those applications that offer the best benefits for facilitating information storage, management, sharing, collaboration, and dissemination.

1. Strategy

The DoD employs a management process known as the Defense Acquisition System to provide timely, useful, and cost-effective systems to its troops. When a specific defense-related need is identified, an Acquisition Program is funded and organized to provide a solution. While the Acquisition Strategy based most of its acquisitions on concepts delineated in the National Security Strategy, it also is poised to “support not only today’s force, but also the next force, and future forces beyond that.” (DoDD 5000.1, 2003) To support future forces, present-day consideration of the best-

suited IT acquisitions is vital to the overall maintenance of a modernized and technologically superior Armed Force. Within the DoD Acquisition infrastructure, a Science and Technology (S&T) program exists to address user needs, and to maintain a broad-based program spanning all Defense-relevant technologies to anticipate future needs. At present, Evolutionary Acquisition (EA) is the preferred DoD strategy for rapid acquisition of mature technologies, as it delivers capability in increments and considers the possibility of future technological improvements. (DoDD 5000.1, 2003)

2. IT Investments

Within the Department of Defense Acquisition System, IT programs strive to treat acquired systems as long-term investments rather than mere acquisitions. As such, the prospect for a system's life cycle is an important consideration with new investments. In accordance with legislation such as the Information Technology Management and Results Act (ITMRA), effective August 8, 1996, and the better known Clinger-Cohen Act, the DoD seeks to develop and use performance metrics to best measure the benefits gained in an IT investment process. This legislation places focus on the life cycle management of IT and the processes supported by that technology, and ensures that IT initiatives proceed, on schedule, toward milestones which meet the user's requirements and deliver intended benefits. High risk or new technology projects receive closer scrutiny and more points of evaluation and review. (Browning, 2005)

C. KNOWLEDGE MANAGEMENT

Few realize that the information age, as known today, dates back to the year 1956. Over the course of the 20th century, the percentage of work force employed in agricultural and manufacturing industries declined significantly. This trend continues into the 21st century. Fifty years ago, the year 1956 marked the date in which automated processes enabled more employment in "knowledge work" than other fields. Since then, society has evolved in many ways, quickly adopting new information technologies to take advantage of the constant advances in communication and computing speeds, and data storage capacities. With a myriad of available options in a constantly expanding IT market, managers frequently look for ways to justify the expenses that come with new hardware, software, and computing options.

The underlying assumption of knowledge management is that modern day information-centric organizations have two types of resources: people and IT. Knowledge management is characterized by a process of “systematically and actively managing and leveraging the vast stores of knowledge and information that exist within a typical company.” Through knowledge management metrics, an organization’s knowledge assets can be identified and enhanced to improve overall performance. (McKeen & Smith, 2003)

1. Knowledge as an Asset

Knowledge should be considered an asset to an organization, similar to known assets like capital, labor, natural resources, and machinery. Like these other assets, knowledge has no value unless it is used. Conversely, knowledge is very different from these familiar assets. First, knowledge can be used without being consumed, exists independently of space (it can be in more than one place at a time), and is very sensitive to time. Secondly, knowledge is extremely abundant, making it contrary to the law of economics which implies that value is a derivative of scarcity, not abundance. Third, the cost structure of knowledge-intensive goods is very different from the cost-structure of physical assets, where the cost of an initial product may be significantly higher than replications of that product, (i.e., software). Finally, there is no correlation between knowledge input and knowledge output. Creative work depends on the individual, and the value of knowledge therein cannot be related to the cost of acquiring that knowledge. Knowledge does not follow the common principles of economics, and must be analyzed in a manner quite different from ordinary economic resources. (McKeen & Smith, 2003)

2. Strategies for Knowledge Management

In order to effectively manage the knowledge assets in an organization, a strategy must be in place. There are five primary tasks inherent in organizations for knowledge management: 1) generating knowledge, 2) accessing knowledge, 3) representing and embedding knowledge, 4) facilitating knowledge, and 5) generalizing knowledge. (McKeen & Smith, 2003)

Generating knowledge implies that organizations must constantly foster new ideas and develop new and improved processes. This can be done by investing in human capital, implementing methods of rewarding innovation, and by applying new knowledge

as it is generated. Accessing knowledge includes the development of policies and processes that not only capture knowledge, but also developing the tools to use that knowledge. In representing and embedding knowledge, it is known that knowledge comes in a variety of different forms. These forms include skill sets, experience, or brainpower. Most knowledge is tacit, meaning it is understood but not expressed. However, a good strategy will have a method of minimizing tacit knowledge by representing knowledge and embedding it within the organizational structure. Similarly, a good strategy will include a way of emphasizing the role knowledge plays within the organization's day-to-day successes. This can be accomplished through experimentation and socialization, or through a leader's empowerment of the knowledge process. Finally, generalizing knowledge means that the organization must be able to adapt to its environment, be flexible and responsive, and achieve true organizational learning. Organizational learning and knowledge management are co-dependent. (McKeen & Smith, 2003)

D. REAL OPTIONS

Real Options Analysis is a market-based methodology invented to address the investment challenges faced by corporations in the modern day economy. It suggests that corporate valuation depends less on traditional fundamentals, and more on future expectations. The traditional discounted cash flow analysis methods: the income, cost, or market approach, tend to view risk and return on investment in a static view. Dr. Johnathan Mun, an expert in Real Options Theory, and credited with making it operational in practice, theorizes that not all risk is bad; in fact, upside risk can often be advantageous. Upside risk is defined simply as the opportunities that coincide with the threats for any given risk. Dr. Mun's interpretation of Real Options is often described as "a new way of thinking," and he views capital investments in terms of a dynamic approach, since all decision making processes have generic and dynamic options associated with them. Real Options Analysis is done by considering these real options, then using options theory to evaluate physical, vice financial assets.

Dr. Mun identifies eight phases in the real options process framework. The first phase begins with the qualification of projects through management screening, which

eliminates all but those projects management wants to evaluate. The second phase starts with the construction of a discounted cash flow model under the base case condition. Next, Monte Carlo simulation is applied, and the results are inserted in the real options analysis. This phase covers the identification of strategic options that exist for a particular project under review. Based on the type of problem framed, the relevant real options models are chosen and executed. Depending on the number of projects as well as management set constraints, portfolio optimization is performed. The efficient allocation of resources is the outcome of this analysis. The next phase involves creating reports and explaining to management the analytical results. This step is critical in that an analytical process is only as good as its expositional ease. Finally, the last phase involves updating the analysis over time. (Mun, 2002) Real options analysis adds tremendous value to projects with uncertainty, but when uncertainty becomes resolved through the passage of time, old assumptions and forecasts have now become historical facts. Therefore, existing models must be updated to reflect new facts and data. This continual improvement and monitoring is vital in making clear, precise, and definitive decisions over time.

E. TERRESTRIAL LASER SCANNING TECHNOLOGY

This research will examine the relatively new and developing terrestrial 3-dimensional laser scanning technology, and its related hardware and software components. While there are a variety of laser scanning models available on the market, this research will use statistical information collected from Spatial Integrated System's 3DIS model (Figure 1). SIS has developed a proprietary approach to digital modeling (2D or 3D) that will be addressed.



Figure 1. SIS Laser Scanning Equipment (courtesy of SIS, Inc.)

3DIS is employed as a 3D image and data capture system. Upon its setup and execution, 3DIS works by scanning its predetermined environment: a compartment, or selected area within that compartment, with a pinpoint of laser light to quickly and accurately capture the digital space and distance information of that space or area. At the same time, an embedded wide angle digital camera captures a photo image of the target. Once this data is captured, the technology automatically implements image-processing algorithms, and a digital point cloud results (Figure 2). The graphical user interface (GUI) of the system portrays this point cloud as faint lines outlining the images within that space. The actual file created is a long list of raw data in the form of (x,y,z) coordinates, and as an added feature, each point retains its original color information. These data points can then be connected and enhanced to create a realistic, 3D model.

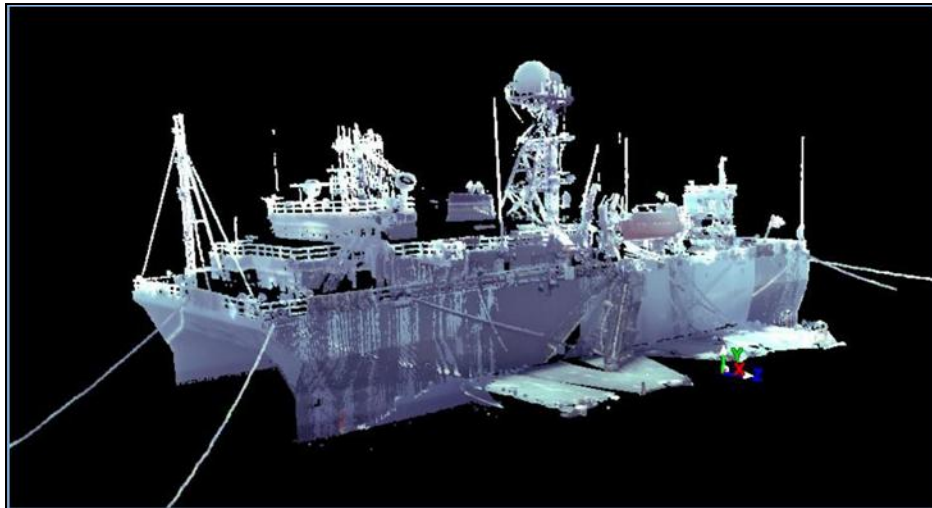


Figure 2. Sample Point Cloud Image (USNS Ship Exterior)

The file format used in the 3DIS system can be exported for further processing, such as 3D CAD analysis and modeling. The process for modeling the captured point cloud is more complex, and can be accomplished by way of several different paths. This path is typically used for a whole compartment or topside area.

1. A point cloud is captured and saved by 3DIS Imager, the software which runs on the scanner.
2. The point cloud is viewed via 3DIS Viewer for a quick check of the data and point-to-point measurements.
3. Captured point clouds are registered to one another using Imageware, a point processing application.

4. A surface model is constructed from the point cloud data.
5. The created surface model is imported into a CAD system and an assembly model of the space and components is completed.
6. Files are exported to AUTOCAD, as required.
7. Detailed information, such as engineering notes and dimension call-outs are added in AUTOCAD.²

Completion of this process provides a workable, 3D model of the captured area or compartment. From this model, prospective alterations can be visualized, accurate dimensions can be ascertained, and most importantly, the model may be reused many times over the life cycle of the naval vessel, and for vessels of the same class. Figure 3, below, shows a completed 3D model composed from a series of point cloud images.



Figure 3. Digital 3D Model of USNS Superstructure

Commercial uses of this technology have ranged from maritime and space applications, to manufacturing and production. There is evidence to suggest that the market for laser scanning technology is expanding. SPAR Point Research recently reported that market estimates for laser scanner applications would experience a 45 percent increase in 2005. (Greaves, 2005) This estimate was yielded from interviews with software and service providers, and laser scanner manufacturers, who report increasing activity in a wide variety of markets, including civil infrastructure, ship and boat building, and automobile manufacturing.

In addition to this research, the National Shipyard Research Program (NSRP), a program designed to research methods to reduce naval ship construction and repair cost,

² Information on the operation of the laser scanning equipment and its proprietary software, including these seven steps listed here, was provided by Spatial Integrated Systems Subject Matter Experts.

funded a study to explore the potential benefits of capturing ship check data in digital format, processing the digital data, and creating 3D CAD models from that data. To date, this study is still in progress. However, this data capture study coincided with NSRP's implementation of a Common Parts Catalog at several U.S. shipyards. Along with this accomplishment, a successful demonstration of digital design data transfer between many design tools occurred. These events bring to light the remarkable, recent progress made towards Naval System Sea Command's (NAVSEA) goal of a common, interoperable IT framework for ship construction, and life cycle management enterprises. NSRP's work with data interoperability refers to an Integrated Shipbuilding Environment (ISE) in which business processes and IT systems are able to accept, transfer, and disseminate electronically. In this environment, information can be entered once and reused many times. (Product Interoperability, 2005)

F. COLLABORATIVE TECHNOLOGY

The market for collaborative technologies is also experiencing growth. Created as an integrated set of IT-enabled functionalities, collaborative technologies enable synchronous and asynchronous communication. At the same time, this type of technologically-enhanced collaboration allows simultaneous, real-time information sharing regardless of the user's geographical location. While many collaborative technologies exist, the most prominent in practice are internet-based applications, especially where users are geographically distributed. Collaborative technologies can be especially effective by allowing groups to communicate, collaborate, and share knowledge regardless of time and space. (Gallaher & O'Rourke, 2004)

1. Collaboration as an Information Strategy

UGS, a leading global provider of product lifecycle management (PLM) software, develops enterprise solutions with innovation in mind. Their work reflects the company's method of consolidating systems, and employing a data structure to allow for collaboration. The capabilities provided by the PLM enterprise strategy include streamlined processes, gained efficiencies, controlled costs, and connected systems and people for unified decision-making. Additionally, UGS software allows for the creation and management of 3D models. In fact, UGS creates or manages 40 percent of the

world's 3D data. (UGS website, 2005) The concepts employed by UGS in its PLM, and the capabilities of its software applications as a planning yard tool will be addressed in the "radical to-be" scenario of this research.

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III. THE KNOWLEDGE VALUE ADDED METHODOLOGY

A. THE VALUE PROBLEM

Before investigating the potential returns or benefits knowledge assets, either human or IT, can provide, one must understand the concept of “value.” When new and promising IT resources are introduced into an organization, the value derived may take a variety of intangible forms, such as improved market competitiveness, expanded markets, new capabilities, or increased efficiency. What value an organization receives from that IT asset depends on many factors beyond the entire capability of the asset, such as organizational culture, the management climate, and the organization’s commitment to training and maintenance. Also important to note is the percentage of the IT resource’s full potential that is actually in use. If the asset is rarely used or used at baseline functionality, then the perceived and actual value derived from the IT asset is likely low. Leveraging people, technologies, and information effectively within an organization can promote team cohesion and provides value.

In other definitions of value, financial metrics tend to prevail. In fact, most value assessments focus on return and cost of ownership for IT investments. Monetary benefits are determined in commercial applications by assigning a price per unit to each process output. However, these financial-based methods seldom capture the benefit streams produced by processes and resources in common, comparable units of measurement. At the same time, financial metrics and benefits are difficult to apply in private-sector and government organizations. The DoD, for example, will not be able to establish the monetary benefits, or the value added from combat effectiveness, operational readiness, and national defense. Therefore, an alternate common unit must be used to determine the value added in public-sector process analysis.

B. THE KVA SOLUTION

The Knowledge Value-Added (KVA) methodology provides a framework for the analytical analysis of organizational knowledge assets. Developed by Drs. Thomas Housel (Naval Postgraduate School) and Valerny Kanevsky (Agilent Lab), the theory of KVA has been published internationally, and has been applied in academic research and

various business consultations for over 15 years. Executed properly, KVA will measure the value of knowledge embedded in an organization's core processes, employees, and IT investments. This measure is quantified in a return-on-knowledge (ROK) ratio, which can be used to identify how much value knowledge assets provide within each core business process. In instances where revenue comparisons or other market-comparable values are available, a return on investment (ROI) figure can be ascertained.

1. The Theory of KVA

With its roots in the Information Age, the theory behind KVA follows the basic principles of thermodynamics by purporting that organizational outputs can be described in units of complexity. More specifically, KVA theory is based on the concept of entropy, which connotes changes in the environment. It follows that as all organizations collect input from various sources and add value in some way, the inputs are transformed to outputs, and the value added during that transition is proportionate to the amount of transformation necessary to change the inputs to the desired output. A unit of change, therefore, is considered simply as a unit of complexity. Belief in this assertion provides a method by which all organizational outputs can be measured in common units. The value added to each process comes from organizational knowledge assets: people, processes, capabilities, or information technology. Through estimation of this value, an analytical method for estimating the return on knowledge, using the knowledge inherent in organizational assets to describe process outputs with a common unit of measurement, is achieved.

The knowledge used every day in the core processes of an organization can be translated to a numerical format, because knowledge is a surrogate for the process outputs measured in common units. By capturing corporate knowledge into value, with clear figures to measure the value contained in each process, decision and policy makers can reengineer processes to maximize value. Then, by seeing the returns each process generates, better decisions can be made for an organization. Whether the knowledge is contained in IT systems or in the minds of an organization's employees is irrelevant, because common units of knowledge can be observed in the organization's core processes, and measured in terms of cost. Similarly, this approach provides management a verifiable way to assign benefit streams and costs to sub-organizational outputs

produced by its knowledge assets, and can effectively redirect management's investment focus from cost containment to value creation.

Figure 4, below, shows a visual depiction of the KVA methodology's underlying model and primary assumptions.

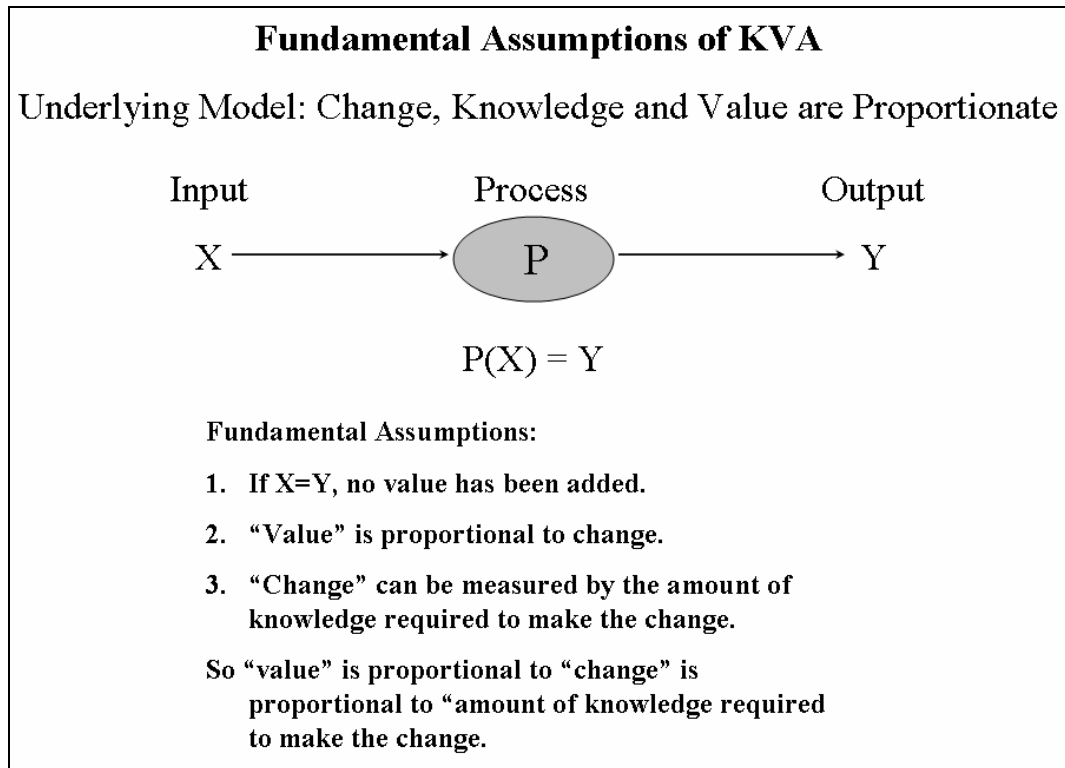


Figure 4. Assumptions of KVA (Housel & Bell, 2001)

The assumptions presented in Figure 4 are the foundation of the KVA process. Accepting these assumptions allows the methodology to work in a way that breaks all input down into a common unit of output, allowing all processes to be evaluated from a common baseline reference. Because of this, how data is collected, analyzed, and how easily it can be monetized, the methodology functions much like accounting. As such, KVA results can be utilized in corporate finance and valuation problems.

2. Core Process Identification

In order to translate the knowledge utilized in an organization's core processes to numerical form, it is important to accurately define what those core processes are, and to define the amount of change each process produces. Typically, corporate executives or other Subject Matter Experts are able to identify the main processes executed by their

organization. In some instances, work flow models exist and may be referenced. In most instances, five to seven core processes sufficiently cover the core processes executed by an organization. For each of those processes, boundaries must be established by identifying the end output of the process, including all subprocess outputs that eventually create the end product. Any contribution IT provides to the process must be isolated.

3. Approaches to KVA

The knowledge within a process can be represented as learning time, process instructions, or information bits. In theory, any approach that satisfies the basic KVA assumptions will create the same results; however, it must capture the “know-how” in the production of process outputs, given particular inputs. Table 1 illustrates the steps used in three primary methods used to apply KVA. The Binary Query Method will not be addressed in this research.

Steps	Learning time	Process description	Binary query method
1.		Identify core process and its subprocesses.	
2.	Establish common units to measure learning time.	Describe the products in terms of the instructions required to reproduce them and select unit of process description.	Create a set of binary yes/no questions such that all possible outputs are represented as a sequence of yes/no answers.
3.	Calculate learning time to execute each subprocess.	Calculate number of process instructions pertaining to each subprocess.	Calculate length of sequence of yes/no answers for each subprocess.
4.	Designate sampling time period long enough to capture a representative sample of the core process's final product/service output.		
5.	Multiply the learning time for each subprocess by the number of times the subprocess executes during sample period.	Multiply the number of process instructions used to describe each subprocess by the number of times the subprocess executes during sample period.	Multiply the length of the yes/no string for each subprocess by the number of times this subprocess executes during sample period.
6.	Allocate revenue to subprocesses in proportion to the quantities generated by step 5 and calculate costs for each subprocess.		
7.	Calculate ROK, and interpret the results.		

Table 1. Three Approaches to KVA (Housel & Bell, 2001)

a. Learning Time Approach

In the learning time approach, the amount of knowledge embedded in a core process is represented by an estimate of the amount of time it would take an individual of average ability to learn that process's execution well enough to successfully

create the same process output. In capturing this estimate, learning time is proportional to the amount of knowledge learned, and thus indicates how much knowledge is embedded in that process. In the context of this methodology, this figure is called “Actual Learning Time,” or ALT. Learning Time must be measured in common units of time, and these units represent common units of output, which are described by the variable K . Following this line of thought, a single execution of any process is equal to a single unit of output, represented by a given number of common units, K .

The obvious question, then, is how one correctly estimates how long it would take for an average person to learn a certain process. In practice, most Subject Matter Experts can provide quality estimates based on formal training times, on-the-job training, training manuals, and other programs, given a minimum explanation of what ALT is in terms of the KVA methodology. It is important that SMEs understand that for each estimate, knowledge must only be counted when it is in use; otherwise, there is a tendency to overestimate the amount of knowledge contained in a given process. Further, knowledge must only be counted if it is truly necessary to execute the process. The shortest, most succinct approach to the process output must be considered, again, to avoid overestimation.

b. Establishing Reliability

Critics would argue that the Learning Time Approach is subjective and anecdotal. However, several methods exist to ensure reliability and confidence of all estimates. The most common way of ensuring reliable estimates is by calculating the correlation between the ALT, ordinal ranking, and relative learn time (RLT) for each process. A correlation value greater than or equal to 80% is sufficient for establishing reliability, and is the preferred method of proving the estimates credible. The three terms are described in detail below:

- Actual Learn Time (ALT) is an estimate for the period of time it would take to teach an average individual to execute a given process. There is no limit to the amount of time required.
- Ordinal Rank is a measure of process complexity described as its difficulty to learn. Subject Matter Experts, or Executives within an organization are asked to rank the processes in order from that which is easiest to learn, to that which is the most difficult to learn.

- Relative Learn Time (RLT) is a measure of the time it would take to teach an average individual the core processes of an organization given only 100 hours, days, months, or other unit of time. Subject Matter Experts or Executives must allocate the time appropriately to each process, with regard to that process's complexity.

Estimates may also be verified using actual knowledge measures such as on-the-job training time, or the number of process instructions within each core process. However, attaining a high degree of correlation and reliability between ALT, RLT, and Ordinal Rankings is the preferred method. (Housel & Bell, 2001)

c. Total Learning Time

The amount of knowledge embedded into the existing IT used in each core process must be captured. This estimate is best achieved by considering what percentage of a process is automated. This percentage estimate for IT is used to calculate the total learning time (TLT), and revenue is allocated proportionally. Interestingly, the revenue attributed to IT-based knowledge, plus the cost to use that IT, often reveals that the value added to processes by IT applications, shown in the resulting ROK ratio, is not always equal to the percentage of IT and automation used in a process. (Housel & Bell, 2001)

d. Process Instructions Approach

In some cases, the Process Instruction Approach must be used to gain reliability of estimates. This approach requires Subject Matter Experts to truly break apart each core process into the various subtasks that comprise it, in order to describe the products in terms of the "instructions required to reproduce them." By capturing the actual learning time of the subprocesses, one is better able to assign reliable estimates of the knowledge contained therein. Just as the case in the Learning Time Approach, it is important that the estimates cited in Process Instructions only contain the knowledge required, or "in use" during execution of each individual process, without overlap. By adding the ALT results for each subprocess within a core process, one has a more reliable estimate of the core process's ALT.

4. Measuring Utility and Knowledge Executions

A count must be taken to determine the number of times the knowledge is executed (value) and the time it takes to execute (cost) in a given sample period. These values are needed to determine the ROK value. The actual time it takes to execute the process, multiplied by cost, is a flow-based estimate of its cost. It is important to note

that process costs alone, without reference to value, present a different picture of the core process's value.

5. The Relevance of Return on Knowledge (ROK)

The return ratio known as ROK is expressed with a numerator representing the percentage of revenue allocated to amount of knowledge required to complete a given process successfully, in proportion to the total amount of knowledge required to generate the total outputs. The denominator of the equation represents the cost to execute the process knowledge. With knowledge as a surrogate for the process outputs measured in common units, a higher ROK signifies better utilization of knowledge assets. In this way, KVA makes it possible to measure how well a specific process is doing in converting existing knowledge into value. Similarly, it gives decision-makers an idea of how an investment in knowledge and learning is paying off, and not simply how much it costs. The ROK value provides decision makers an analytical way to determine how knowledge can be more effectively used to produce better return on performance. If increased automation does not improve the ROK value of a given process, steps must be taken to improve that process's function and performance.

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IV. METHODOLOGY PROOF OF CONCEPT

A. INTRODUCTION

The Puget Sound Planning Yard is located in Bremerton, Washington, and is one of four public-sector U.S. Navy planning yards. Responsible for planning the maintenance and modernization ship alteration jobs scheduled for the aircraft carriers stationed on the west coast and Japan, alongside the minesweeper force based in Ingleside, Texas, the Puget Sound Planning Yard boasts a mature work force and a well established shipcheck process. The remaining three public Navy shipyards, along with their respective planning yards, are located in Norfolk, Virginia, Portsmouth, Maine, and Pearl Harbor, Hawaii.

The following Proof-of-Concept analysis will use the “as-is” process information compiled from interviews and conversations with a select group of Subject Matter Experts from the Puget Sound Planning Yard. Their input will be analyzed and verified by independent sources, and all estimates will be aggregated to reflect the cost and number of process executions for all U.S. public planning yard facilities. The KVA methodology will be applied to analyze the theory that reengineered planning yard processes, with focus on the shipcheck, could positively affect the Navy’s maintenance and modernization efforts. IT assets will be introduced in two sequential, notional scenarios. If introduction of IT has an effect on current planning yard processes, it will be evident in increased ROK values, and associated cost estimates. These figures will be shown as a comparison of the current, “as-is” scenario to the “to-be,” and “radical to-be” scenarios using defensible future process estimates.

B. THE PURPOSE OF PLANNING YARDS

The first step in determining the potential value of an IT investment requires analysis of the current process in place. While the concept of a shipyard carries a basic conceptual understanding, the planning yard, which operates in support of shipyards and myriad other customers, is less intuitive and seldom understood outside of the industry. Planning Yards serve an essential support role within the larger framework of the Fleet Modernization Program. For every ship maintenance or modernization task mandated by

the Department of the Navy (DoN), the Planning Yard receives funding through the Design Services Allocation (DSA), along with technical guidance and tasking orders to prepare the shipyard to complete that task. The DSA is a funding line with provisions for design and SHIPALT development work, including Ship Alteration Requests (SAR), Ship installation drawings (SID), Liaison Action Requests (LAR), and Ship Service Request (SSR) update including Configuration Overhaul Planning (COP). SHIPALTS constitute an order mandating the introduction, design, or installation of change to naval vessels.

Planning Yards must compile all applicable data and job-related information for its end users, which is generally an industrial activity of some sort. The end user may be the shipyard itself, a private-sector shipyard, or an entity independent of the planning yard and shipyard. This work is necessary so that physical work required to accomplish a SHIPALT may be planned and accomplished with minimal system or human conflict. Ideally, all system interferences, problems, or conflicts relating to assigned SHIPALTS will be resolved by planning yard. Planning Yards strive to achieve these tasks, among others, and to create quality installation drawings through the execution of a well tested process, and the retention of seasoned, experienced employees.

The standard documents considered to be planning yard products, or “outputs,” include 2-dimensional (2D) detailed AUTOCAD drawings of ship compartments or installation areas, equipment removal routes, and material lists. Less tangible outputs of this process include ship’s force/shipyard accord in regard to equipment configuration, and the assurance that alteration-specific capacities, such as sufficient chill water or electrical capacity for certain alterations, meet the requirements for a given SHIPALT.

Figure 5 graphically depicts the organizational hierarchy of public Navy Planning Yards. Although variations may exist between planning yard locations in terms of number of branches, and the type of staff support services required, all planning yards will be based on the organizational structure below:

Planning Yard Organization

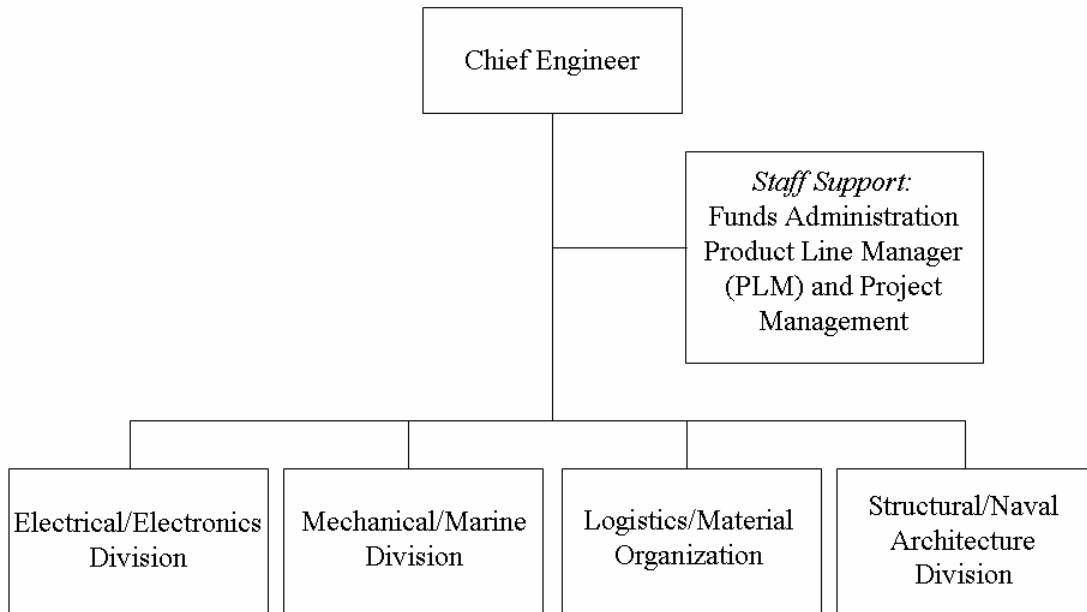


Figure 5. Universal Planning Yard Organization³

C. DATA COLLECTION METHODOLOGY

Aggregate data was gathered during an initial KVA knowledge audit conducted in a group interview setting, at the shipyard location in Bremerton, Washington. At the initial meeting, five planning yard Subject Matter Experts (each having an expertise in one of four primary disciplines) and current employees of Puget Sound Planning Yard were present. Each of the five Subject Matter Experts has over 20 years experience in the planning yard industry, with a high degree of expertise in his affiliated discipline. A workflow model of the planning yard process (Figure 6) guided the interview.

³ To facilitate understanding of the planning yard process, this model was developed by Unified Industries Incorporated (UII) prior to the initial Group Interview in Bremerton, Washington, and disseminated to SIS vendor representatives and the NPS research team.

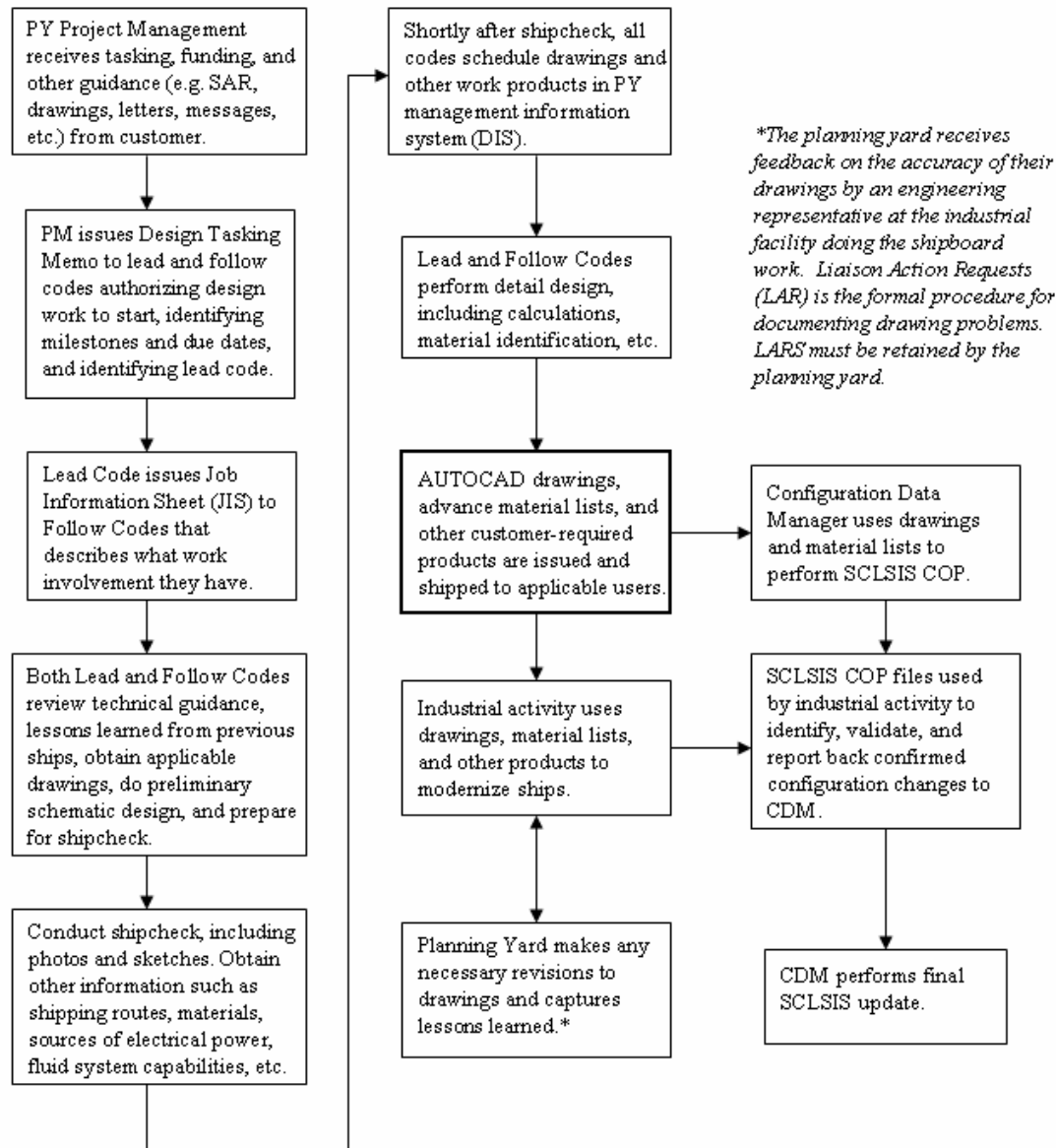


Figure 6. Planning Yard Workflow Model

1. Learning Time Method

The method of analysis for this Proof of Concept is the Learning Time method. By interviewing the Subject Matter Experts (SME) in a group setting, it was possible to extract and establish consensus on what processes constitute the core planning yard processes, identify the inputs and outputs of those processes, and determine the frequency of core process iterations. Boundaries were established between the defined processes in order to effectively apply the KVA methodology, and to properly identify and value the knowledge required for each. The planning yard experts defined seven core processes,

and described each to a great level of detail. Each core process requires a certain level of knowledge in one or more of the following areas: administration, management, scheduling, budgeting, basic computer skills, drafting, engineering, shipboard systems, or AUTOCAD drafting and drawing development. The Subject Matter Experts spent considerable time contemplating the amount of knowledge embedded in each core process, and provided learning time estimates for each. The established baseline level of knowledge for consideration was a GS-6 employee with a college degree (no field specified). Finally, the team of Subject Matter Experts provided individual and uninfluenced relative learning time and rank order estimates to establish the level of reliability on the ALT figures obtained.

2. Process Instruction Method

Preliminary analysis of the initial learning time estimates resulted in an insufficient level of correlation between learning time estimates and rank order estimates. As such, it was necessary to greater detail to evaluate each core planning yard process. During the process instructions interview session, Subject Matter Experts were asked to break each core process down into its component subprocesses, and in doing so, provide better estimates for the overall core process ALT by summing up the new values. As established in the KVA theory, the subprocess learning time estimates can be backward allocated to each core process for greater reliability and degree of confidence. The resulting and currently standing ALT calculations for the core processes were derived from the developed process instructions, and a correlation of greater than 80 percent was attained.

D. THE DEFINED PLANNING YARD PROCESSES

To best understand how a business process may be improved by way of reengineered or automated processes, one must first understand the current, “as is” process. Subject Matter Experts described seven sequential core processes that encompass all planning yard work. To best reference each core process, unofficial titles were coined, as shown in Figure 7.

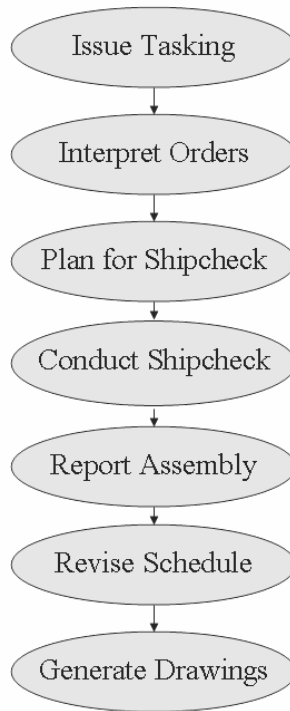


Figure 7. Planning Yard Core Processes

This chain of core processes is executed for every naval vessel as it approaches its shipyard availability period. The schedule, timeline and location for ship availabilities are established by Navy leadership far in advance, but calendar dates and work assigned may be constrained by budget allowances and other prioritization factors. Further, availability schedules may be affected if world events trigger an unanticipated demand for operational naval assets. For example, the terrorist attacks of September 11, 2001, and Operation Iraqi Freedom prompted major changes in the employment of naval forces. These events resulted in an ultimate surging to deploy seven carrier battle groups, and the largest Amphibious Task group assembled since World War II. To enhance its readiness, the Navy implemented the Fleet Response Plan in May of 2003, which extends the scheduled time between ship availabilities from 24 months to 27 months. (H.R. Rep. No. GAO-04-724R, 2004) It is not certain what effect this availability delay will have on the Fleet material condition.

The core processes defined by the group of SME for operations at Puget Sound Planning Yard are described in detail below. Operations at alternate public planning yards are assumed comparable in scope, duration, and knowledge requirements.

1. Issue Tasking

In the planning yard, a cycle of the core processes initiates when planning yard leadership receives formal tasking from a government source, which is ultimately regarded as the “customer.” Because Navy ships operate with availability periods planned well in advance, tasking and funding is typically in line with a ship availability schedule, and is not unexpected. However, the number and type of ship alterations that must be planned is variable. Hence, the tasking order provides funding and direction for what the planning yard must accomplish on a given ship, and planning may begin.

The current process begins when the planning yard receives formal tasking to accomplish work on a specific platform. This tasking is traditionally delivered via email. The Project Manager (PM) must then consolidate and organize all tasks into an internal planning yard document called a Design Tasking Memorandum (DTM). The DTM is issued to all applicable parties: the Lead and Follow Codes who, by virtue of their specialization, will accomplish a portion of the work contained within the DTM. A “Lead Code” is the subspecialty which has the most significant role in a given alteration assignment. Similarly, a “Follow Code” is the subspecialty who must perform work in a given assignment, but whose related subject matter skill set falls secondary to that of the lead codes’ because of the nature of the task. Subject Matter Experts identified three subtasks of “Issue Tasking,” which includes budget and schedule planning, and the Production Line Manager’s (PLM) management of the overall process.

2. Interpret Orders

Disseminated via the planning yard’s email network, the DTM must be reviewed by all Lead and Follow Codes. Lead Codes must use the guidance contained in the DTM to begin preparations for their assigned ship alterations. There will be one lead code for each SHIPALT, and because there may be many SHIPALTs, many Lead Codes may exist in planning for one shipcheck. Similarly, there may be many follow codes assigned to one SHIPALT. To prepare for the shipcheck, Lead Codes collect and review official guidance and previously generated SHIPALT records to assist them as they produce Job

Information Sheets (JIS). All JIS documents are distributed electronically via email to applicable Follow Codes for a given SHIPALT, so that Follow Codes are aware of their responsibilities. Subject Matter Experts discussed three subtasks for the “Interpret Orders” core process, including communication between Lead and Follow Codes, beginning the SHIPALT data collection process, and the creation of the JIS.

3. Plan for Shipcheck

At this point, all Lead and Follow Codes are in receipt of their official guidance: the DTM and its respective JIS documents. In this planning phase, all Codes begin more formal preparations for the actual shipcheck. The duration of this process can vary since it is largely dependant on how much time exists between tasking and the actual shipcheck event. Shipcheck planning primarily entails data collection and collaboration between Lead and Follow Codes, but there are also subprocesses critical to the success of the shipcheck. In this phase, a shipcheck team is formed with consideration to the volume and complexity of SHIPALTs to be planned. The Program Manager must contact the Commanding Officer (CO) of the shipcheck platform to verify its location and schedule. Finally, as the date of the shipcheck nears, the physical tools needed for work are assembled.

4. Conduct Shipcheck

Planning yard customers sometimes fall outside of the waterfront shipyard organization. More often than not, however, planning yard products, which include 2-dimensional CAD drawings, material lists, and equipment access routes, are often used by the actual shipyard facility to accomplish its mission of maintaining and modernizing the U.S. Naval Fleet. Clearly, shipyard work requires significant planning before any worker can turn a wrench or make an installation. For this reason, a shipcheck must always precede the actual ship availability period. To begin this phase, the shipcheck team must first travel to the ship’s location. For Puget Sound Planning Yard, travel is normally required to either San Diego, California, or Japan. The team size and length of shipcheck depends on number of SHIPALTs, experience level of team members, and the complexity of the assigned tasks. Subject Matter Experts agreed that a good estimate for shipcheck team size would be 30-35 personnel, representing both Lead and Follow

Codes. Also, it was determined that the average length of a shipcheck was 10 working days, or two weeks. For the entire shipcheck, one Group Leader will be assigned.

Many activities occur during the shipcheck, including space walkthroughs, meetings, compartment sketching, and coordination with ship's crew. These activities are designed to validate "as is" ship configuration, to assess the compartments, equipment, or system intended for alteration to ensure systems will not conflict, and to plan equipment removal and entry routes. Also, perhaps the most important product of the shipcheck process is rough sketches drawn to-scale, to later enter into CAD software to develop 2D drawings.

5. Report Assembly

Following the actual SHIPCHECK, the Lead Code, specifically, the Lead Designer, must assemble a SHIPALT Report. In doing this, he or she must coordinate with all follow codes to accurately document all system conflicts that may result from implementation of the modernization and maintenance tasks at hand. The SHIPALT Report is distributed to project stakeholders.

6. Revise Schedule

Once the SHIPCHECK is complete, the data collected during the process is taken and entered in to large database called DIS. Once all data is entered into DIS, a report called the "Drawing Schedule" is automatically produced. This Drawing Schedule automatically generates a revised schedule, and appropriate cost and manhour estimates. From these figures, the Program Manager can inform the customer of the expected cost and schedule, and revisions will be made as required.

7. Generate Drawings

Referencing the drawing list, the Lead Designer has the ultimate responsibility to ensure that sketches completed as part of the shipcheck are verified, developed, and completed in the standard CAD 2D format, as required by the FMP. With each drawing, the applicable material list will be included. Planning Yards generally expect to complete at least five ship installation drawings (SID) for every SHIPALT assigned, although the number of drawings varies. Completed drawings are delivered to the customer, as ordered, and used to facilitate maintenance and modernization work in industrial activities.

E. KVA ANALYSIS OF “AS IS” SCENARIO

A summary of the high level “as is” KVA analysis is depicted in Table 2, which contains the core planning yard processes. While all initial estimates were compiled from Puget Sound Planning Yard sources, the overall analysis and data values have been aggregated to reveal information relevant to all four public-sector planning yards. All estimates contained in this analysis are as conservative and accurate as possible.

“AS IS” Planning Yard Process Overview
Values Reflect Estimates for all U.S. Public-Sector Planning Yards

Core Process	Process Title	# Org	Est. # Shipcheck per Org	Head Count per Shipcheck	Daily Salary	Times Fired per Shipcheck	Time (days)	Total Learning Time	Rank Order	Total Benefits	Total Cost	ROK
1	Issue Tasking	4	10	2	\$271.10	1	8	898	5	35984	\$173,500.00	0.21
2	Interpret Orders	4	10	5	\$226.20	100	10	536	4	2142000	\$520,000.00	4.12
3	Plan for Shipcheck	4	10	35	\$226.20	1	6	250	3	9984	\$1,655,000.00	0.01
4	Conduct Shipcheck	4	10	35	\$271.10	1	10	1323	6	11327940	\$2,604,500.00	4.35
5	Report Assembly	4	10	1	\$226.20	1	6	426	2	1383240	\$235,000.00	5.89
6	Revise Schedule	4	10	1	\$226.20	1	3	326	1	1288144	\$131,000.00	9.83
7	Generate Drawings	4	10	110+	\$226.20	500	18	830	7	16590000	\$39,386,000.00	0.42
“AS IS” PROCESS TOTALS:										32777292	\$44,705,000.00	0.73

Table 2. Core Planning Yard Process Overview

1. Head Count

The “Head Count” column represents the number of employees assigned to complete the given process for each cycle, or iteration. The numbers assigned are based on interviews with Subject Matter Experts, who agreed that the average shipcheck team composition is 35 personnel, including representatives of all Lead and Follow Codes. By accounting for the number of personnel involved in each process, it can be determined how often knowledge is used. It also provides an approximate way to weight the cost of using knowledge in each process.

2. Times Fired

The estimate for “Times Fired” is the aggregated number of occurrences of each process by public-sector planning yards, per year. This value was achieved by looking at statistical information for fiscal years 2003, 2004, and 2005, and by considering the estimates provided by the Subject Matter Experts at Puget Sound Planning Yard.

According to the testimony of Rear Admiral Mark A. Hugel, Deputy Director for Fleet Readiness, in fiscal year 2003, 95 ship and submarine maintenance availabilities occurred. The following year, fiscal year 2004, 73 maintenance availabilities were funded, with additional funding granted to perform depot and intermediate-level maintenance on 42 additional ships returning from Global War on Terrorism (GWOT) deployments. Finally, there were 85 planned availabilities for fiscal year 2005. (Hugel, 2005) Puget Sound Planning Yard estimates that it performs the preliminary availability planning work on five platforms annually, and stressed that number can vary greatly year to year. However, Puget Sound performs the work on aircraft carriers and minesweepers, which constitute a small percentage of the entire Navy Fleet. To remain conservative, and to properly account for planning yard work outsourced to private industry, this study approximates that work across the four public planning yards amounts to 40 shipchecks per year. As such, all “times fired” estimates were multiplied by this value for proper aggregation.

Similarly, the Subject Matter Experts concluded that approximately 140 SHIPALTS were planned during the course of one shipcheck, and for each assigned SHIPALT, approximately five drawings (process outputs) are created. Again, because of the nature of Puget Sound’s specific hull assignments, it is likely that their average experience may be higher than the actual Fleet shipcheck (per ship) average. For this analysis, it is assumed that 100 SHIPALTS occur per shipcheck process. Furthermore, of these 100 SHIPALTS, an expected breakdown would be: 25 low-complexity alterations (a modification to a component or set of components), 25 high-complexity alterations (a modification to a major system), and 50 medium-complexity alterations (a modification to a subsystem). Estimates in this analysis will be based on estimates for SHIPALTS of medium-complexity, the likely mean and most common SHIPALT performed.

3. Actual Learning Time

In order to determine the actual learning time from a common point of reference, the Subject Matter Experts were instructed to imagine a baseline individual of a college graduate at the GS-6 civilian rank level, having earned a college degree. All experts understood that each process learning time estimate must adhere to the basic assumptions that knowledge is only counted if in use, and the most succinct path to achieve a unit of

output must be considered. Each core process was broken down into its component subprocesses through the process instruction approach, and respective ALT values were assigned for each subprocess. The final ALT value for each core process is a summation of the subprocess ALT estimates. Finally, all ALT values are based on the following time assumptions:

- One year = 230 work days
- One month = 20 work days
- One week = 5 work days
- One day = 8 hours

4. Ordinal Ranking

Executed as a process independent of the ALT estimates, Ordinal Rank Order provided the Subject Matter Experts a straightforward way to rank each core process in terms of their view of its relative complexity. Because perception of process complexity can vary, the exercise was conducted in a manner to minimize peer interaction and influence. In the ranking process, the number one (1) represents the core process considered the least complex and easiest to learn, while the number seven (7) represents the most complex and difficult to learn. All processes are ranked in between accordingly. As previously discussed, the value in this exercise is attainment of level of reliability that learning time estimates are satisfactory. This reliability is calculated through the statistical method of correlation. The values in the ALT column must correlate well with the rank order numbers. Achieving a correlation result greater than 0.80 is considered sufficient and ALT estimates should be accepted. The level of correlation for the “as is” scenario is 0.84.

5. Knowledge in IT

Each process contains a certain degree of process automation, ranging from zero percent to 100 percent. It is important to estimate precisely how much of each process is automated, and to be consistent in those estimates, so that the knowledge embedded in the technology resources is accounted for. Upon determination of the percentage estimate, the Total Learning Time (TLT) is calculated based on that percentage. Because it accounts for the knowledge embedded in the information technology assets of the organization, the TLT value is used to derive the “benefits” of each process.

6. Cost Estimation

The collection of cost-related information was relatively simple, since information on human capital cost for government employees is public information. For cost calculations, the 2005 GS salary pay table was referenced. Since various steps and slight differences in pay exist within each GS rank, salary figures are based on the midpoint average pay of GS-12 planning yard employees (\$62,353/year) and GS-11 employees (\$52,025/year). It was determined that most planning yard processes executed are accomplished by personnel within these rank levels. Research also indicates that Puget Sound carries a more mature work force than other shipyards; however, in this instance cost estimates will be based on what is known to exist at the Puget Sound location. Also, because basic computing hardware and software is utilized in every scenario, IT cost is not included in the “as is” analysis. It is assumed that each employee in this process has an email account, laptop or desktop computer with identical software, and access to a printer. Material, travel, and other miscellaneous costs are not included in this analysis so labor cost may be isolated.

7. “As-Is” Process Data Analysis

Each core process below contains its respective process instructions in table format. It is important to evaluate each subprocess in detail, as later comparison in the “to be” and “radical to be” scenarios are best explained at this level of detail.

a. Key Assumptions

As mentioned, this analysis is based on information collected at Puget Sound Planning Yard. Because all Planning Yards operate under the guidance of the FMP, it is assumed that all processes are comparable. Also, it is well known that all shipcheck-related processes can vary in number, manpower requirements, duration, and complexity. After many interview sessions with planning yard SME in person, via teleconference, or through email, the following assumptions were made:

- Between the four public sector planning yards, 40 shipchecks are accomplished. Other naval shipchecks are outsourced to private planning yards.
- The level of effort for each shipcheck is 100 SHIPALTS.
- All estimates assume a SHIPALT of medium-complexity.
- Each shipcheck team averages 35 personnel.

- The duration of a shipcheck is 10 workdays, with a travel day at each end.
- For each SHIPALT, at least five sketches/drawings are created.
- For each SHIPALT, approximately 10 digital photographs are captured.
- Each SHIPCHECK will have five Lead Codes, and many Follow Codes.

b. “Issue Tasking” KVA Analysis

Table 3 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process one:

Core Process 1: Issue Tasking															
1	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
1a.	Plan SHIPCHECK budget allocations.	4	10	1	1	5	\$271.10	30%	1	0	1	x	52	\$54,220	0.00
1b.	Coordinate and build schedule.	4	10	1	1	3	\$271.10	30%	1	0	1	x	52	\$32,532	0.00
1c.	PLM oversee entire task.	4	10	1	1	8	\$271.10	30%	690	207	897	x	35880	\$86,752	0.41
TOTALS		4	10	2	1	8	\$271.10	x	690	208	898	5	35984	\$173,504	0.41

Table 3. Core Process One “As Is” KVA

As a management-based task, this process yields expected results. The total cost is relatively low, as very few employees are involved in the scheduling and budget aspects of delivering the DTM, the output of this core process. The overall cost was predictably low in relation to other processes because the rank structure of those employees involved in the included planning yard processes is more horizontally-oriented than most other organizations; the salaries used are that of either a GS-11 or GS-12, depending on the process. The ALT values contained in the “*plan shipcheck budget allocations*,” and “*coordinate and build schedule*” were reduced to one day, because the knowledge which allows the PLM to oversee the task cannot overlap with these two activities. This reduction enabled proper application of KVA methodology.

c. “Interpret Orders” KVA Analysis

Table 4 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process two:

Core Process 2: Interpret Orders															
2	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
2a	Coordinate and communicate with follow codes and outside organizations.	4	10	5	100	2.5	\$226.20	5%	120	6	126	X	504000	\$113,098	4.46
2b	Begins data collection pertaining to tasking.	4	10	5	100	5	\$271.10	5%	230	12	242	X	966000	\$271,100	3.56
2c	Create Job Information Sheet (JIS) for each unique "job."	4	10	5	100	2.5	\$271.10	40%	120	48	168	X	672000	\$135,550	4.96
TOTALS		4	10	5	100	10	\$226.20	X	470	66	536	4	2142000	\$519,748	4.12

Table 4. Core Process 2 “As Is” KVA

Like the previous core process, the “Interpret Orders” core process has predictable return on knowledge results, but it uses the knowledge assets of more personnel, and is executed more often. Because creation of the JIS is already an automated process, and one which depends on user input and coordination among the Lead and Follow Codes, there is no evidence to suggest this process should be changed. However, there is potential for improvement in the work time required to “begin data collection pertaining to tasking.” Minimizing this work time with an improved way to manage and access information, would further improve the ROK. Relative to other core processes, however, a ROK of 4.12 is positive, implying that this process makes effective use of knowledge resources.

d. “Plan for Shipcheck” KVA Analysis

Table 5 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process three:

Core Process 3: Plan for Shipcheck															
3	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
3a	Form shipcheck team.	4	10	1	1	0.5	\$271.10	5%	2	0	2	x	84	\$5,422	0.02
3b	Get permission to go to ship.	4	10	1	1	0.25	\$271.10	0%	5	0	5	x	200	\$2,711	0.07
3c	Gather data applicable to shipcheck: review guidance, drawings, schematics	4	10	35	1	5	\$226.20	5%	230	12	242	x	9660	\$1,583,370	0.01
3d	Physically gather tools required for SHIPCHECK.	4	10	35	1	0.2	\$226.20	0%	1	0	1	x	40	\$63,335	0.00
TOTALS		4	10	35	1	5.95	\$226.20	x	238	12	250	3	9984	\$1,654,837	0.01

Table 5. Core Process 3 “As Is” KVA

With an annual, aggregated cost of approximately \$1.5 million, the ROK of this process is disproportionately low for all processes. Because this core process is focused on planning for the shipcheck, it requires a tremendous amount of knowledge in proportion to its output: an ensemble of tools and reference material needed by each member of the team for work on the shipcheck platform. Subject Matter Experts stated that finding the tools and reference materials required for each shipcheck executed requires knowledge and experience, because one must know what to look for, where to look for it, and how to acquire the resources needed (i.e., previous SID from shipcheck conducted on same ship class, lessons learned from previous SHIPALTs, etc.). There is no central repository that enables easy access to Navy-wide information, beyond what has already been done “in house” at each Planning Yard facility. Information sharing, and drawings reuse is not common. This process has significant potential for improvement through the implementation of data sharing technology.

e. **“Conduct Shipcheck” KVA Analysis**

Table 6 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process four:

Core Process 4: Conduct Shipcheck															
4	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
4a	Travel time. Transport team to ship.	4	10	35	1	1	\$226.20	0%	1	0	1	x	40	\$316,674	0.00
4b	Manage overall process.	4	10	1	1	9	\$271.10	15%	1150	173	1323	x	52900	\$97,596	0.54
4c	Conduct in-brief and out-brief with ship's crew.	4	10	1	2	0.25	\$271.10	15%	230	35	265	x	21160	\$2,711	7.81
4d	Liaison with ship's crew, including conflict management and resolution.	4	10	1	75	4	\$271.10	0%	460	0	460	x	1380000	\$43,376	31.81
4e	Conduct ship walkthru: identify and resolve interferences between new installations (one for each ALT).	4	10	5	100	4	\$226.20	10%	690	69	759	x	3036000	\$180,957	16.78
4f	Determine alteration-pertinent capacities.	4	10	10	210	2.5	\$226.20	10%	20	2	22	x	184800	\$226,196	0.82
4g	Collect "removal data" for equipment and material to be removed, including temporary access routes.	4	10	10	25	2.5	\$226.20	10%	120	12	132	x	132000	\$226,196	0.58
4h	Create rough sketches and schematic designs for SHIPALTS.	4	10	35	500	2	\$226.20	5%	230	12	242	x	4830000	\$633,348	7.63
4i	Photograph images for SHIPALTS with digital camera.	4	10	3	1000	4	\$226.20	75%	0.50	0.38	1	x	35000	\$108,574	0.32
4j	Create SHIPALT material lists.	4	10	25	100	2	\$226.20	20%	345	69	414	x	1656000	\$452,391	3.66
4k	Travel time. Transport team from ship.	4	10	35	1	1	\$226.20	0%	1	0	1	x	40	\$316,674	0.00
TOTALS		4	10	35	40	10	\$271.10	x	2097.5	371	3618	6	11327940	\$2,604,692	4.35

Table 6. Core Process 4 “As Is” KVA

Simple observation of the large number of subprocesses executed to complete a typical shipcheck reveals that the “conduct shipcheck” core process requires significant knowledge-assets, a large budget, and significant manpower. Interestingly, reducing the time required to conduct a shipcheck provides the greatest opportunity to improve Navy ship cycle time. Executing a shipcheck requires the second highest number of personnel workdays, outside of the “generate drawings” core process. Regardless of the number of personnel on the team, based on the subprocesses and work times estimated by the SME team, accomplishing one SHIPCHECK consumes 286 workdays. This figure explains the relatively high annual cost of \$2.6 million dollars for the completion of 40 shipchecks (recall that planning yard duties outsourced to private industry are not included in this analysis).

Observation of the ROK results indicates that the highest return on knowledge is achieved in the “conduct ship walkthrough” and “liaison with ship’s crew” subprocesses. Considering the low cost of each, and the high return on knowledge each allows indicates effective knowledge management for both processes. Conversely, one might also observe that the most expensive subprocess is “create rough sketches and schematic designs.” This high cost, coupled with a moderate ROK value of 7.63, implies

that the knowledge embedded in the process of creating manual sketches could be better utilized.

f. “Report Assembly” KVA Analysis

Table 7 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process five.

Core Process 5: Report Assembly															
5	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
	Determine and list conflicts between subsystems.	4	10	5	100	5	\$226.20	0%	345	0	345	x	1380000	\$226,196	6.10
	Create SHIPALT Report.	4	10	1	1	1	\$226.20	35%	60	21	81	x	3240	\$9,048	0.36
TOTALS		4	10	1	1	6	\$271.10	x	405	21	426	2	1383240	\$235,243	5.88

Table 7. Core Process 5 “As Is” KVA

Before drafting a SHIPALT Report, the Lead Codes must confer with all Follow Codes and discuss any system conflicts relevant to SHIPALTS. In determining system problems, much knowledge is used, and is properly demonstrated in a high process ROK of 6.10. Recalling the similar process of “conduct ship walk-through” and its high ROK, it follows that determining system conflicts would have a similarly high ROK. In fact, many system conflicts are determined prior to this phase in the overall process. In this example, it is difficult to capture the instances where revisits to the ship for reassessment are necessary, as estimates for the percentage of cases in which this occurs were unavailable. As such, the total cost applied to this core process is likely much lower than reality.

g. “Revise Schedule” KVA Analysis

Table 8 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process six.

Core Process 6: Revise Schedule															
6	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
6a.	Organize data to update DIS.	4	10	10	100	1.25	\$226.20	40%	230	92	322	x	1288000	\$113,098	11.39
6b.	Develop drawing "list" or schedule.	4	10	1	1	1	\$226.20	80%	1	1	2	x	72	\$9,048	0.01
6c.	Expected manhours determined.	4	10	1	1	1	\$226.20	80%	1	1	2	x	72	\$9,048	0.01
TOTALS		4	10	1		3	\$271.10	x	232	94	326	1	1288144	\$131,193	9.82

Table 8. Core Process 6 “As Is” KVA

One of the primary objectives of planning yard work is to determine the budget and manhour requirements for each SHIPALT, so that the industrial activity can properly plan work execution. These estimates are achieved after the shipcheck, by entering applicable data into an on-site database called DIS. Without question, allocating

cost and time to each SHIPALT requires significant knowledge and experience, reflected in the high ALT value for “*organize data to update DIS.*” Within the DIS information system, estimates for cost and time is automatically generated once all SHIPALT information is submitted. Because it is a highly complex process, and managed reasonably, the ROK for this process ranks higher than the others.

h. “Generate Drawings” KVA Analysis

Table 9 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of core process seven.

Core Process 7: Generate Drawings															
7	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Fired per Shipcheck	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Rank Order	Total Benefits	Annual Cost	ROK
7a	Physically develop drawings to be redone in CAD	4	10	110	500	18	\$226.20	5%	690	35	725	x	14490000	\$17,914,696	0.81
7b	Draw and generate 2D drawing using AUTOCAD software.	4	10	110	500	18	\$271.10	75%	60	45	105	x	2100000	\$21,471,120	0.10
TOTALS		4	10	1	500	18	\$271.10	x	750	80	830	7	16590000	\$39,385,816	0.42

Table 9. Core Process 7 “As Is” KVA

Of any process, the subtasks completed in the “Generate Drawings” core process are executed most frequently, based on the SME input that at least five drawings are generated for every SHIPALT performed. In addition, a significant amount of knowledge is used per iteration, and the final output (the drawing) reflects that knowledge. As mentioned in the “Report Assembly” process description, the task of generating drawings sometimes requires repeat visits to ships outside of the actual shipcheck period to validate sketches and ensure accuracy. As stated, an estimate to capture this percentage was unavailable. Similarly, the estimate of five drawings per SHIPALT is conservative, and it may be that in reality, many more drawings are required for complex SHIPALTS. As a result of these two notions, the total cost as calculated is presumably lower than reality. The impact on our analysis, however, is negligible, since conservative estimates are preferred.

F. “TO-BE” PLANNING YARD PROCESS

This scenario portrays a combination of notional and verified data to best represent current planning yard activities, reengineered to maximize utilization of new IT assets. Not every subtask will be affected in this scenario; instead, only affected

processes will be used for comparison. All others may be assumed static and as described in their “as is” state.

1. Cost of IT

The cost for laser scanning equipment and all applicable IT was provided by the Improved Engineering Design Process (IEDP) Project Manager for SIS. For this study, the cost for IT was amortized for a 10 year period. Given an initial cost of \$88,000 for one 3DIS scanner plus its applicable software suite, a maintenance/upkeep annual cost estimate of 20 percent, a use estimate of 200 days per year, and a lifespan estimate of 10 years, the resulting cost per day is: \$132.00. For analysis of the “to be” KVA, this cost is absorbed by the actual scanning process, and not distributed evenly among the processes that utilize the software suite for modeling. This cost is based on the logistical ideal that one 3DIS scanner is shared between two planning yards. Finally, 3DIS is rated for a lifespan of 20 years, although it is likely that system technological improvements would warrant an upgrade well before 20 years. In reality, technological advancements tend to warrant IT product replacement well before their promised lifespan. However, even with a five year expected lifespan, given the same maintenance assumptions, cost for this product is negligible at \$176.00 per day.

2. Reengineered Processes

The primary change from the “as is” process to the “to be” is the introduction of Spatial Integrated System’s 3DIS laser scanner system and 3D data capture technology. Implementation of this system into the planning yard process will cause the process output to change from static installation drawings delivered on paper, to 3D digital images and models able to guarantee accuracy and precision. Also, an added third dimension provides greater value to end users. To account for this added value, outputs of the “to-be” process affected by the technology were assigned a conservative increase of 20%. An important note is that although the output is in 3D, the 2D drawing currently required by FMP policy is easily created. Because appropriate stakeholders would still benefit from the 3-dimensional models, the value is conserved, while downstream shipyard processes which require 2D drawings would be supported until a new policy and IT-based infrastructure supporting 3D digital imagery is implemented.

Table 10 depicts the change in cost and ROK values from the “as is” to the “to be” scenario. Again, all values are aggregated to capture the cost for four public-sector shipyards. The majority of the estimates contained in this KVA analysis were obtained from SIS Representatives, Puget Sound Planning Yard Subject Matter Experts, and various Trade Engineers with backgrounds in CAD 2D drafting and 3D modeling.

Core Process	Process Title	Annual "AS IS" Cost	Annual "TO BE" Cost	Difference	"AS IS" ROK	"TO BE" ROK
1	ISSUE TASKING	\$173,500	\$173,500	\$0	0.41	0.41
2	INTERPRET ORDERS	\$520,000	\$520,000	\$0	4.12	4.12
3	<i>PLAN FOR SHIPCHECK</i>	\$1,655,000	\$714,000	\$941,000	0.01	0.01
4	<i>CONDUCT SHIPCHECK</i>	\$2,604,500	\$1,364,000	\$1,240,500	4.35	12.56
5	REPORT ASSEMBLY	\$235,000	\$235,000	\$0	5.88	5.88
6	REVISE SCHEDULE	\$131,000	\$131,000	\$0	9.82	9.82
7	<i>GENERATE DRAWINGS</i>	\$39,386,000	\$4,716,000	\$34,670,000	0.42	15.13
TOTALS		\$44,705,000	\$7,853,500	\$36,851,500		

Table 10. “As Is” and “To Be” Cost and ROK Value Differences

Evident in the above table, despite the additional expense of the laser scanning system, the overall cost is still reduced by over \$36 million dollars. It is apparent that the cost-savings are achieved in the core processes directly influenced by new technology: process three, four, and seven. Valuation of the return on knowledge of each process also shows that through the introduction of IT, the utilization of knowledge resources within those processes improved. Finally, cost savings and return on knowledge improvements will be more visible and evident over time, as the technology matures, and becomes better implemented into the current process. Work time and manpower requirements will decrease, and the quantity of 3D models available for reuse will increase.

3. “To Be” Data Analysis

Reengineering a notional, “to be” scenario presented several challenges. First, complete understanding of the current process was necessary before any alternate scenarios could be theorized. Second, to make reasonable and conservative estimates of a “to be” scenario, knowledge of the capabilities and limitations of the proposed IT resources, and their place within that current process, was required. Finally, the

practicality of the IT resources, and the usefulness of 3D models and its respective products beyond the confines of the planning yards, were considered in each scenario.

For greater understanding, Core Process three, four, and seven will be scaled down to each group of subtasks. Since no values changed in the other processes, they will not be included in this section.

a. “Plan for Shipcheck” To Be KVA Analysis

Table 11 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “to be” revision of process three. Core process one and two are omitted because introduction of 3D data capturing technology had no influence on those tasks.

"To Be" Core Process 3: Plan for Shipcheck														
3	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK
3a.	Form shipcheck team.	4	10	1	1	0.5	\$271.10	5%	2	0	2	84	\$5,422	0.02
3b.	Get permission to go to ship.	4	10	1	1	0.25	\$271.10	0%	5	0	5	200	\$2,711	0.07
3c.	Gather data applicable to shipcheck: review guidance, drawings, schematics	4	10	15	1	5	\$226.20	5%	230	12	242	9660	\$678,587	0.01
3d.	Physically gather tools required for SHIPCHECK	4	10	15	1	0.2	\$226.20	0%	1	0	1	40	\$27,143	0.00
TOTALS		4	10	15	1	5.95	\$226.20	x	238	12	250	9984	\$713,863	0.01

Table 11. KVA Analysis of To Be “Plan for Shipcheck” Process

Several assumptions were made that account for the cost-savings reflected in the processes associated with planning a shipcheck. First, use of the laser scanning technology reduces the number of personnel necessary for the shipcheck team, because the process of manual hand sketching has been superseded. The revised team size in this scenario consists of 15 personnel, reduced from the original “as is” size of 35. As such, only 15 personnel will need to gather information in preparation for each shipcheck. At the same time, access to stored digital information from previous shipchecks will improve the data collection process. Changed values are shown in red.

b. “Conduct Shipcheck” To Be KVA Analysis

Table 12 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “to be” revision of process four.

"To Be" Core Process 4: Conduct Shipcheck															
4	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK	
4a.	Travel time. Transport team to ship.	4	10	15	1	1	\$226.20	0%	1	0	1	40	\$135,717	0.00	
4b.	Manage overall process.	4	10	1	1	9	\$271.10	15%	1150	173	1323	52900	\$97,596	0.54	
4c.	Conduct in-brief and out-brief with ship's crew.	4	10	1	2	0.25	\$271.10	15%	230	35	265	21160	\$2,711	7.81	
4d.	Liason with ship's crew, including conflict management and resolution.	4	10	1	75	4	\$271.10	0%	460	0	460	1380000	\$43,376	31.81	
4e.	Conduct ship walkthru: identify and resolve interferences between new installations (one for each ALT).	4	10	5	100	4	\$226.20	10%	690	69	759	3036000	\$180,957	16.78	
4f.	Determine alteration-pertinent capacities.	4	10	10	210	2.5	\$226.20	10%	20	2	22	184800	\$226,196	0.82	
4g.	Collect "removal data" for equipment and material to be removed, including temporary access routes.	4	10	10	5	2.5	\$226.20	10%	120	12	132	26400	\$226,196	0.12	
4h.	Scan & capture point cloud images for applicable areas and compartments.	4	10	1	500	8	\$226.20	95%	276	262	538	10764000	\$72,383	148.71	
4i.	Photograph images for SHIPALTS with digital camera.	4	10	1	500	4	\$226.20	75%	0.50	0.38	1	17500	\$36,191	0.48	
4j.	Create SHIPALT material lists.	4	10	10	100	2	\$226.20	20%	345	69	414	1656000	\$180,957	9.15	
4k.	Travel time. Transport team from ship.	4	10	15	1	1	\$226.20	0%	1	0	1	40	\$135,717	0.00	
TOTALS		4	10	15	40	x	\$271.10	x	2143.5	622	3915	17138840	\$1,337,996	12.81	

Table 12. KVA Analysis of To Be "Conduct Shipcheck" Process

Reducing the time required to complete this process will provide the greatest potential to reduce the time required to conduct shipchecks, and increase the time a Navy ship is available for operational tasking. Again, the shipcheck team size has been reduced from 35 to 15 personnel. In place of hand-sketched ship installation drawings, a laser scanner captures a point cloud image of the area or compartment specified in the SHIPALT. It is important to realize the fundamental change in this scenario: where a single sketch was once created for each required SID, the laser scanner can now capture a model from which an infinite number of 3D and 2D images, image redesigns, and the SHIPALT required installation drawings (SIDS), can be produced. For this exercise, it is assumed that 20 area or compartment scans are required to achieve the same level of output as the current "conduct shipcheck" scenario.

Laser Scanner Developers have documented performance times that reveal the time to capture a reliable, average quality point cloud is two to three hours for a low complexity space, such as a ship's fan room, four to six hours for a medium complexity space, such as a stateroom or office space, and eight to 12 hours for a high-complexity space, such as Combat Information Center (CIC) or a Main Machinery Room (MMR). These estimates are based on laser scanning work accomplished on 25 different Navy ships in recent years. The estimate used in this core process is four hours; that is, the time to capture a compartment of medium complexity. Experts agree that as experience and technology improve, the time required to capture a quality scan will be significantly reduced. In fact, the most recent 3DIS model created by Spatial Integrated Systems (SIS)

reduces these documented scan times by 50 percent. For each compartment scanned, one system operator is sufficient. Obviously, the time required on board is directly proportional to the number of scanners, and scanner operators available to complete the required work.

For the specific subtasks reengineered to include 3D laser scanning or digital images, the ALT values were increased by a conservative 20 percent to reflect the additional knowledge embedded in a more valuable output. Three dimensions are inherently more complex than two dimensions. As is evident in the below table, the ROK of the “*scan and capture point cloud images*” process increased considerably. At the same time, the cost to execute this process is moderate, despite the cost of the laser scanner and software suite (price \$132/day over 10 year period, not shown in table).

c. “Generate Drawings” To Be KVA Analysis

Table 13 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “to be” revision of process seven. Again, core processes five and six are omitted because introduction of 3D data capture technology had no influence on those tasks.

"To Be" Core Process 7: Generate Drawings														
7	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK
7a.	Physically develop drawings to be redone in CAD.	4	40	440	500	48	\$226.20	5%	600	35	725	14490000	\$17,914,606	0.84
7b.	Conduct data processing for captured point clouds. (point processing)	4	10	10	500	7	\$226.20	10%	828	83	911	18216000	\$633,348	28.76
7c.	Model processed data to 3D.	4	10	10	500	45	\$226.20	75%	828	621	1449	28980000	\$4,071,600	7.12
7d.	Generate 2D drawings.	4	10	10	500	0.125	\$226.20	75%	690	518	1208	24150000	\$11,310	2135.28
TOTALS		4	10	1	500	5	\$226.20	x	1380	552	1932	71346000	\$4,716,258	15.13

Table 13. KVA Analysis of To Be “Generate Drawings” Process

As learned in analysis of the “as is” process to generate drawings, it is the most time-consuming task executed by planning yards. Experts note that on average, a typical AUTOCAD drawing requires approximately 40 hours of “thinking” and 40 hours of actual drawing in the software.⁴ Of course, this depends greatly on the complexity of the drawing and the number of systems affected by the SHIPALT. Much of the “thinking,” and “drawing,” is actually done concurrently. With the introduction of 3D digital capture technology, the bulk of the drawing development task is no longer required, since the laser scanner automatically captures the image, and with 3D imaging,

⁴ This estimate has two sources: personal e-mail received from an engineer with 20 years planning yard and CAD experience, with agreement from a Branch Manager at Puget Sound Planning Yard.

engineering an alteration is simplified. With less problem-solving required to apply the mandated alteration to the current configuration, work time is significantly reduced.

Data processing is a necessary subprocess of this task. After an image point cloud is captured, data processing occurs. To accomplish this, a human operator establishes relationships between the “points in space” captured in the point cloud, using point processing software. This step replaces the “as is” task of physically engineering and drawing a SID on paper to be recreated in a CAD or AUTOCAD application. Actual 3D modeling follows this step, which replaces the former step of drawing the 2D SID in AUTOCAD. While the “*model processed data to 3D*” has a high total cost, the downstream benefit is enormous, reflected in the considerable ROK of “*generate 2D drawings*.” From a purely analytical vantage, the ROK figure is large because the work time is significantly reduced from the previous “as is” subtask which created 2D drawings in CAD. Using the 3D model generated in this “to be” scenario, however, creation of a 2D paper drawing may be likened to a snapshot within the software application. The improved return on knowledge in this notional scenario, particularly in the “*generate 2D drawings*” subprocess, is noteworthy.

G. “RADICAL-TO-BE” PLANNING YARD PROCESS

1. Reengineered Processes

This notional scenario presents the ideal state for Planning Yards, with maximum employment of laser scanners, 3D digital imaging, data warehousing, a robust database management system (DBMS), and collaborative environments. In reality, a reasonable transition to this state might take many years. All organizational transition takes time, effort, and a common effort. Starting with revised policy, a strategic goal, an acquisition effort in line with the revised policy and strategy, appropriate test locations for gradual evaluation, and finally, large-scale implementation in the planning yard environment, evolving to the state of readiness portrayed in this radical scenario is feasible.

To best present this scenario, collaborative environment specialists at UGS Corporation, a leading global provider of product lifecycle management software and services, were interviewed. The core processes and subtasks were reengineered appropriately to reflect the value added through a collaborative environment. Moreover,

because of the nature of technology is to evolve and improve, this scenario assumes ship 3D data is accessible to all stakeholders in the planning yard process. It also assumes minor decreases in laser scanner capture and required modeling work time. In this scenario, revisions to the FMP replace the requirement for 2D physical ship installation drawings with digital images, accessible via a network. As one indirect advantage, all stakeholders have instant access to all data generated by any planning yard or industrial activity. The most obvious advantages of collaborative environments are seen in those processes pertaining to planning.

As evident in the Table 14, the cost savings introduced in this scenario are significant. The following sections will explain each reengineered process in detail.

Comparison Between As Is and Radical To Be Cost and ROK Values						
Core Process	Process Title	"AS IS" Cost	"RADICAL TO BE" Cost	Difference	"AS IS" ROK	"RADICAL" ROK
1	ISSUE TASKING	\$173,500	\$173,500	\$0	0.41	0.41
2	INTERPRET ORDERS	\$520,000	\$328,000	\$192,000	0.27	8.46
3	PLAN FOR SHIPCHECK	\$1,655,000	\$374,500	\$1,280,500	0.01	0.05
4	CONDUCT SHIPCHECK	\$2,604,500	\$1,041,000	\$1,563,500	0.26	17.53
5	REPORT ASSEMBLY	\$235,000	\$122,000	\$113,000	0.61	11.32
6	REVISE SCHEDULE	\$131,000	\$131,000	\$0	1.12	9.82
7	GENERATE DRAWINGS	\$39,386,000	\$2,319,000	\$37,067,000	0.46	30.77
TOTALS		\$44,705,000	\$4,489,000	\$40,216,000		

Table 14. “As Is and “Radical To Be” Cost and ROK Comparison

2. Radical “To Be” Data Analysis

The following tables are theoretical interpretations built on the previous “as is” scenario iteration, and portray how implementation of a planning-yard specific collaborative environment could affect the “as is” process by promoting interoperability, reusability of products, and knowledge sharing. Any “as is” or “to be” values changed are annotated in blue. Unaffected core processes are not discussed.

a. “Interpret Orders” Radical “To Be” KVA Analysis

Table 15 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “radical to be” revision of process two.

"Radical To Be" Core Process 2: Interpret Orders															
2	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Manhours (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK
2a.	Coordinate and communicate with follow codes and outside organizations.	4	10	5	100	1.25	6.25	\$226.20	50%	120	60	180	720000	\$56,549	12.73
2b.	Begins data collection pertaining to tasking.	4	10	5	100	2.5	12.5	\$271.10	50%	230	115	345	1380000	\$135,550	10.18
2c.	Create Job Information Sheet (JIS) for each unique "job."	4	10	5	100	2.5	12.5	\$271.10	40%	120	48	168	672000	\$135,550	4.96
TOTALS		4	10	5	100	6.25	31.25	\$226.20	x	470	223	693	2772000	\$327,649	8.46

Table 15. KVA Analysis of Radical To Be “Interpret Orders” Process

A primary assumption of this scenario is that a collaborative environment has been created, allowing all stakeholders and shipcheck-planners instant, real-time access to a database of reusable 3D images collected over time from various planning yard facilities. The collaborative environment also promotes effective coordination and communication between many engineers. As a result, communication and data collection tasks work times are reduced by 50 percent. Similarly, because of the amount of technology applied to a once manual process, the percentage of IT increased. These factors enabled the ROK of this process to double over previous scenarios, and reduced cost by roughly 40 percent.

b. “Plan for Shipcheck” Radical “To Be” KVA Analysis

Table 16 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “radical to be” revision of process three.

"Radical To Be" Core Process 3: Plan for Shipcheck															
3	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Manhours (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK
3a.	Form shipcheck team.	4	10	1	1	0.5	0.5	\$271.10	5%	2	0	2	84	\$5,422	0.02
3b.	Get permission to go to ship.	4	10	1	1	0.25	0.25	\$271.10	0%	5	0	5	200	\$2,711	0.07
3c.	Gather data applicable to shipcheck: review guidance, drawings, schematics	4	10	15	1	2.5	37.5	\$226.20	75%	276	207	483	19320	\$339,293	0.06
3d.	Physically gather tools required for SHIPCHECK.	4	10	15	1	0.2	3	\$226.20	0%	1	0	1	40	\$27,143	0.00
TOTALS		4	10	15	1	3.45	41.25	\$226.20	x	284	207	491	19644	\$374,570	0.05

Table 16. KVA Analysis of Radical To Be “Plan for Shipcheck” Process

This core process is also focused on planning for a shipcheck. Consequently, the same assumptions from the “interpret orders” process may be applied here; engineers may find necessary SHIPALT data more quickly and easily through a collaborative interface. This assumption justifies the work time reduction to two and a half days per worker, rather than the “as is” work time of five days. With instant access to data from other Planning Yards and SHIPALTS, shipcheck teams will be more prepared for the work at hand. Constructive, time-saving problem solving discussion can

occur among the Lead and Follow Codes and other outside organizations prior to the actual shipcheck.

c. “Conduct Shipcheck” Radical “To Be” KVA Analysis

Table 17 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “radical to be” revision of process four.

"Radical To Be" Core Process 4: Conduct Shipcheck															
4	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Manhours (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK
4a.	Travel time. Transport team to ship.	4	10	15	1	1	15	\$226.20	0%	1	0	1	40	\$135,717	0.00
4b.	Manage overall process.	4	10	1	1	5	5	\$271.10	15%	1150	173	1323	52900	\$54,220	0.98
4c.	Conduct in-brief and out-brief with ship's crew.	4	10	1	2	0.25	0.25	\$271.10	15%	230	35	265	21160	\$2,711	7.81
4d.	Liason with ship's crew, including conflict management and resolution.	4	10	1	75	4	4	\$271.10	0%	460	0	460	1380000	\$43,376	31.81
4e.	Conduct ship walkthru: identify and resolve interferences between new installations (one for each ALT).	4	10	5	100	2	10	\$226.20	50%	690	345	1035	4140000	\$90,478	45.76
4f.	Determine alteration-pertinent capacities. Collect "removal data" for equipment and material to be removed, including temporary access routes.	4	10	10	210	2.5	25	\$226.20	10%	20	2	22	184800	\$226,196	0.82
4g.	Scan & capture point cloud images for applicable areas and compartments.	4	10	2	500	2.5	5	\$226.20	95%	276	262	538	10764000	\$45,239	237.94
4h.	Photograph images for SHIPALTS with digital camera.	4	10	1	500	4	4	\$226.20	75%	0.50	0.38	1	17500	\$36,191	0.48
4i.	Create SHIPALT material lists.	4	10	10	100	2	20	\$226.20	20%	345	69	414	1656000	\$180,957	9.15
4k.	Travel time. Transport team from ship.	4	10	15	1	1	15	\$226.20	0%	1	0	1	40	\$135,717	0.00
TOTALS		4	10	15	40	x	113.25	\$271.10	x	2143.5	946	4239	18252440	\$1,041,281	17.53

Table 17. KVA Analysis of Radical To Be “Conduct Shipcheck” Process

This process contains an assumption that scan times will be reduced. In reality, a scanner capable of the work time presented here already exists, but documented data is not yet available.⁵ A ship compartment of medium-complexity can be scanned in two hours, with one operator. In this scenario, two scanners are available, so the duration of the shipcheck may be reduced. Also, removal data information can be determined by looking at 3D ship models prior to going onboard, and time spent executing this process during the actual shipcheck will be for verification purposes only. Time required to complete the ship walk-through process has been reduced because the majority of system and subsystem conflicts were identified and resolved quickly and easily in the planning stage. As such, shipcheck walk-through procedures are also primarily for verification. If problems or unexpected difficulties arise during the shipcheck, they may be addressed through a collaborative interface, and access to many engineering experts is possible.

What is most notable about this “radical to be” reengineered process is the significant cost savings and impressive ROK improvements. Because of reduced

⁵ SIS reports its new model, released in the Fall, 2005, reduces its predecessor's scan times by 50 percent.

manpower requirements, minimal shipcheck duration, and better utilization of knowledge assets, cost was reduced from the “as is” scenario by 50 percent, and the process ROK increased by 450 percent.

d. “Generate Drawings” Radical “To Be” KVA Analysis

Table 18 shows all KVA estimates used to determine the total process benefits, annual cost, and return on knowledge (ROK) of the notional “radical to be” revision of process seven.

"Radical To Be" Core Process 7: Generate Drawings															
7	SUBPROCESS	# Units	Shipchecks per Unit	Head Count	Times Fired per SC	Time (days)	Manhours (days)	Daily Salary	%IT	ALT (days)	K in IT	TLT	Total Benefits	Annual Cost	ROK
7a	Physically develop drawings to be redone in CAD.	4	40	440	500	48	4800	\$226.20	5%	690	35	725	44490000	\$17,944,696	0.84
7b	Conduct data processing for captured point clouds. (point processing)	4	10	10	500	3	30	\$226.20	10%	828	83	911	18216000	\$271,435	67.11
7c	Model processed data to 3D.	4	10	10	500	22.5	225	\$226.20	75%	828	621	1449	28980000	\$2,035,800	14.24
7d	Generate 2D drawings.	4	10	10	500	0.125	1.25	\$226.20	75%	690	518	1208	24150000	\$11,310	2135.28
TOTALS		4	10	1	500	5	256.25	\$226.20	x	1380	552	1932	71346000	\$2,318,545	30.77

Table 18. KVA Analysis of Radical To Be “Generate Drawings” Process

It is assumed that as experience in 3D data processing and modeling matures, and software improvements are made, work times for these related subprocesses will decrease. In this reengineered scenario, work times are decreased by 25 percent; reducing the work time for data processing to two days, and model processing to 15 days. Object reuse in this process accounts for 25 percent of all SHIPALTS, reducing the demand to produce new models, decreasing work time further. Again, the improvement from the “as is” ROK value for this core process from 0.42 to 30.77 is phenomenal, and highlights an impressive use of knowledge resources. Similarly, the cost reduction from the current process execution cost of \$39 million dollars annually, to just over \$2 million, is remarkable.

H. THE PRODUCTION VALUE

Digital imaging in 3D and collaborative environments have great potential for improving the various processes employed in maintenance, modernization, and repair production. While outside the actual analysis of planning yard processes, the possibilities these interrelated IT resources provide deserve mention. As is the case within the Planning Yard environment, the 3D scan data and documents relative to planning work, stored as reference data in a database, is instantly available to shipyard Engineers. As such, Engineers have the ability to electronically communicate with many different

experts when needed, view installation drawings, and consider a SHIPALTS actual manufacturability, and material availability much earlier in the process. Collaboration, in this way, provides a unique ability to view, edit, and analyze SHIPALT-pertinent data. Finally, all stakeholders can track work progress and stay abreast of changes. For these reasons, one can easily conclude that the improved capabilities of the planning yards will have a positive impact on all areas of the shipyard industry, including production.

I. FINAL COMPARISONS

The following figures graphically show the cost-savings and manpower reductions introduced by the notional, technology-enhanced scenarios. Of all the core processes presented in this research, the most significant and positive changes occurred in the “conduct shipcheck,” and “generate drawing” core processes. One way to reduce overall cost is to reduce labor expenses. Figure 8 shows the potential reduction in total workdays required, annually, between the four public-sector planning yards to complete 40 shipchecks.

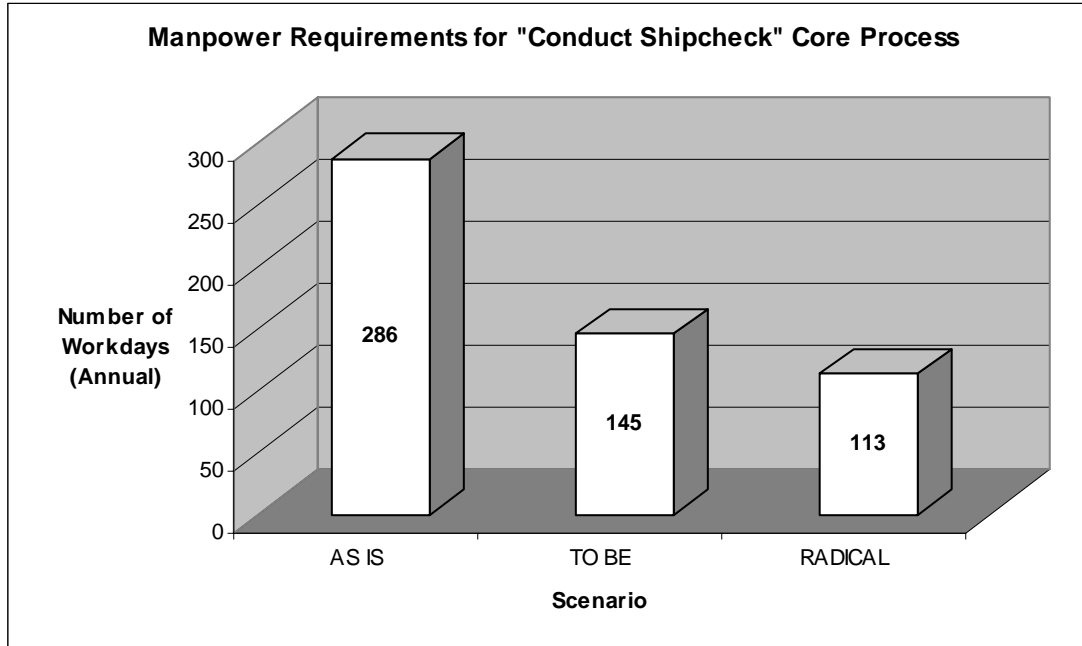


Figure 8. Manpower Comparison Chart for “Conduct Shipcheck” Process

The difference is even more dramatic in the manpower reductions in the “generate drawings” core process. Because a once-manual effort is largely replaced by a more

automated digital capture, and the subsequent creation of a 3D model capable of producing many, reusable 2D or 3D ship installation drawings, the requirement for a large work force is minimized. An annual requirement of roughly 20,000 installation drawings for 40 shipchecks, with 100 SHIPALTS each, can be reduced from 3,960 paid work days (regardless of the number of workers) to only 256 paid work days. Figure 9 depicts this reduction.

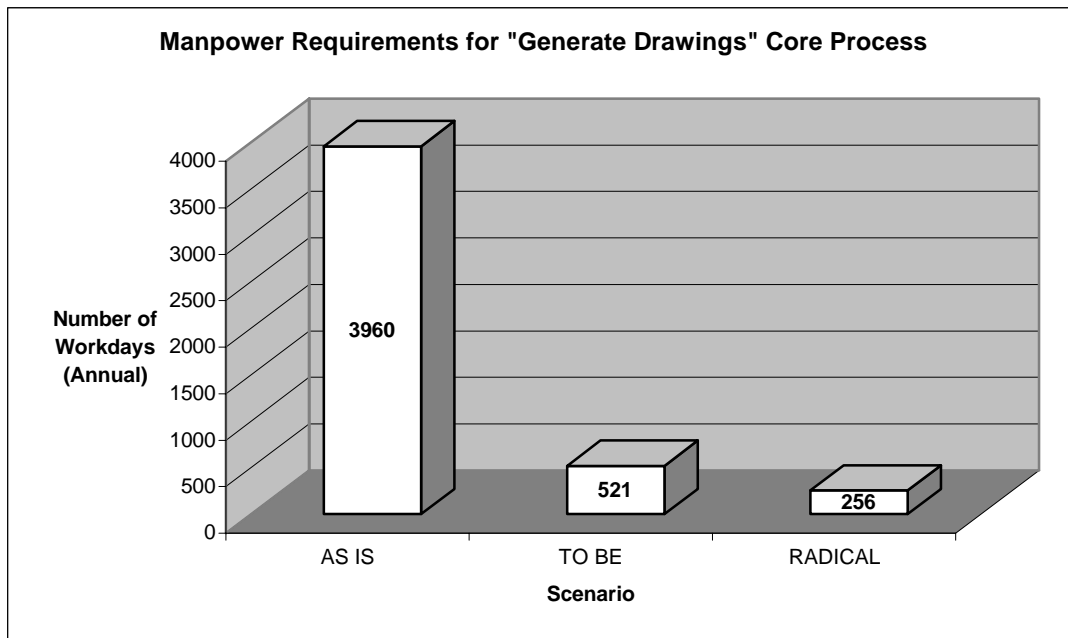


Figure 9. Manpower Comparison Chart for “Generate Drawings” Process

As it is currently executed, the “generate drawings” process is very manpower-intensive. This is because the majority of the process is manual, translating from a sketch on paper, or a pencil-marked revision to a previous SID, to a two-dimensional AutoCAD paper drawing. As evident in the above chart, through automation of the SID, manpower requirements are significantly reduced.

Another means for comparison is established using the cost plus method.⁶ By establishing the revenue for all planning yard processes, the number of outputs (reflected by “total benefits”) is used to establish respective core process revenues. With these core process revenue amounts determined, a derivative form of Return on Knowledge, called

⁶ The cost plus method is a pricing method commonly used by firms, and in government contracts. The common thread in cost plus pricing is that a baseline cost is established, then a percentage is added to account for profit.

Return on Knowledge Investment, (ROKI) may be calculated. The core processes yielding the highest percentage of ROKI can be said to generate the highest return on investment, given the human and IT knowledge-based assets contained in that process, in creating process outputs. Table 19 and Table 20 show the “as is” and “to be” results, respectively. The total core process benefits, percentage of process benefits against the sum of all benefits, revenue, annual cost, ROK and ROKI values for each core process may be compared.

"AS IS" Benefits, Revenue, ROK, and ROKI Values

Core Process	Process Title	Total Benefits	% Benefits	Revenue	Annual Cost	ROK	ROKI
1	ISSUE TASKING	35,984	0.11%	\$53,987	\$173,500	0.41	-69%
2	INTERPRET ORDERS	2,142,000	6.54%	\$3,213,658	\$520,000	4.12	518%
3	PLAN FOR SHIPCHECK	9,984	0.03%	\$14,979	\$1,655,000	0.01	-99%
4	CONDUCT SHIPCHECK	11,327,940	34.56%	\$16,995,392	\$2,604,500	4.35	552%
5	REPORT ASSEMBLY	1,383,240	4.22%	\$2,075,285	\$235,000	5.88	782%
6	REVISE SCHEDULE	1,288,144	3.93%	\$1,932,612	\$131,000	9.82	1373%
7	GENERATE DRAWINGS	16,590,000	50.61%	\$24,890,099	\$39,386,000	0.42	-37%

Table 19. “As Is” Return on Investment Figures

In Table 19, the ROKI for the “*revise schedule*” process is very high. As an automated process—one able to calculate manhours, schedule, and budget requirements, this makes sense. As would be expected, ROKI follows the same trend as ROK, although represented in a different form. The reengineered processes in the “to be” scenario are evident in the improved ROK and ROKI values of processes four and seven, below.

"TO BE" Benefits, Revenue, ROK, and ROKI Values

Core Process	Process Title	Total Benefits	% Benefits	Revenue	Annual Cost	ROK	ROKI
1	ISSUE TASKING	35,984	0.04%	\$53,976	\$173,500	0.41	-69%
2	INTERPRET ORDERS	2,142,000	2.29%	\$3,213,658	\$520,000	4.12	518%
3	PLAN FOR SHIPCHECK	9,984	0.01%	\$14,976	\$714,000	0.01	-98%
4	CONDUCT SHIPCHECK	17,138,840	18.36%	\$25,708,260	\$1,364,000	12.56	1784%
5	REPORT ASSEMBLY	1,383,240	1.48%	\$2,074,860	\$235,000	5.88	782%
6	REVISE SCHEDULE	1,288,144	1.38%	\$1,932,216	\$131,000	9.82	1373%
7	GENERATE DRAWINGS	71,346,000	76.43%	\$107,019,000	\$4,716,000	15.13	2169%

Table 20. “To Be” Return on Investment Figures

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V. CONCLUSIONS AND RECOMMENDATIONS

A. RESEARCH LIMITATIONS

The Proof of Concept was generated from SME input from only one planning yard facility, and generalized for the others based on this input. Therefore, the data contained in this research cannot be assumed perfect. Additionally, because of the maturity and high level of expertise of the select group of interviewees, establishing a high degree of reliability was challenging. There were varying opinions on which processes were the most complex, least complex, and so forth. Furthermore, time and distance restrictions limited the amount of research SME interaction, which compounded the problem. If more time had been available, KVA learning time values would have been collected through use of the process instruction method up front, and more reliable initial estimates would have resulted.

At the same time, 3D data capture technologies cannot be assumed a perfect solution for every ship maintenance and modernization task. For instance, SHIPALTS occurring in compartments with significant piping, wiring, or electrical circuitry may not be ideal candidates for 3D modeling. Furthermore, it is not clear if labor costs and skill sets required for 3D data capture and modeling would be significantly higher than current process rates. Finally, the estimated cost of collaborative technology software was not available for this research. Because software cost tends to be high, the final “radical to be” cost could drastically increase with this revision. Nevertheless, the positive impact of both technologies is still apparent.

B. RESEARCH QUESTIONS

Careful analysis of the Proof of Concept does reveal the significant potential value IT resources may contribute to the Navy shipyard planning process. Digital 3D data capture, with its high quality, accurate, and reusable product outputs, alongside the information storage and sharing capabilities of a collaborative environment, may prove useful in naval ship maintenance and modernization planning and production efforts. As previously mentioned, however, any new IT introduced into modern organizations carries

a certain degree of risk. Application of this KVA methodology to the Planning Yard Proof of Concept has yielded one type of decision support model to demonstrate the potential impact of 3D laser scanners and collaborative technologies within this environment.

Through use of analytical, measurable data, it has been shown that acquisition of these technologies could, over time, significantly decrease cycle time for U.S. Navy ships by expediting maintenance work in shipyards, lessen maintenance costs by eliminating or reducing DOD planning yard labor costs, provide an opportunity to reduce fleet inventory requirements by way of reduced cycle time, and overall, improve productivity in current planning yard shipcheck processes to a degree which would allow for increased shipboard modernization.

1. Navy Fleet Cycle Time

An improved Fleet cycle time allows a higher availability of assets to Operational Commanders at any given time. If availability period durations are reduced, and the same level of work accomplished (i.e., all planned SHIPALTS completed), it would follow that the Fleet Cycle time would be improved. The Proof of Concept case study revealed that shipcheck durations could be reduced by 50 percent. While this value is limited to one specific aspect of the availability process--the planning yard, collaborative environments show much potential to improve production processes. Collectively, if every operational Navy ship was available one additional week for tasking, over a two year time-span, the DoN would have 280 additional weeks for tasking assignments, training, or crew rest and relaxation opportunities.

Further, digital images provide a level of accuracy and promote a sense of trustworthiness that cannot be attributed to the current process of manual hand-sketches, which would eliminate redundant checks and time spent verifying drawings while in production. Finally, with these technologies, information availability becomes less episodic, and would allow Navy planners to schedule minimal maintenance activity and planning between major availability periods, because capturing the data for analysis of study of a space can occur at any time. Downstream processes, including the industrial activity executing the work, will experience reduced work time as a result, further minimizing fleet cycle time.

2. Cost-Savings

Of any potential advantage offered by 3D data capture and collaboration, the cost-savings is the most apparent and profound conclusion. Considering the analysis included only labor costs, plus the added cost of IT within each notional scenario, and that all “to be” and “radical to be” assumptions are defensible, the results are significant.

The U.S. government currently pays nearly \$45 million dollars to complete the shipcheck cycle an estimated 40 times each year. As a reminder, this cost estimate is based solely on labor rates, and excludes expenses such as travel and material. It consists of only those shipchecks conducted by the four public-sector planning yards. In the revised, “to be” scenario, this cost drops to only \$8 million; a remarkable reduction of 84 percent. Interestingly, within the KVA analysis framework, there are two distinct paths one could take to account for this cost savings. The obvious path is achieved by a reduction in manpower, which provides the ability to accomplish the same job with fewer personnel. The other path involves the same number of personnel accomplishing the same task more quickly, and as a consequence, a percentage of the work force would be available for more tasking, alternate tasking, or improved training. Nevertheless, the cost savings potential for this application is worth consideration.

3. Force Planning & Expanded Capability

It is surmised that expediting the planning yard process will, in turn, create a ripple effect through all industrial activity for maintenance and modernization of naval assets. In time, reducing the duration of ship availabilities, and providing more operational availability of naval assets, could provide leadership incentive to reduce the size of the Fleet. On one hand, leadership could schedule increased time gaps between new ship acquisitions, or allow ship decommissioning to occur at an earlier, more realistic phase of its current expected life cycle.

At the same time, Fleet Size is largely dependant on world events, and the operational requirements and goals of the Commander in Chief (CIC). With an improved cycle time for maintenance and modernization activities, a viable option would be increased levels of ship alterations, for the improvement of ship weapons, sensing, propulsion, navigation, or health and habitability issues.

C. REAL OPTIONS

The technologies presented in this research provide a variety of future options, including several phased option scenarios, several instant IT acquisition scenarios, and several which take the technology and expand to other applicable areas. The most valuable of all determined options are listed below:

- Do nothing, allow the current “as is” process to evolve.
- Immediately acquire only the 3D data capture technology, without a collaborative environment, at one planning yard. If successful, expand capability to all public-sector planning yards.
- Immediately acquire both 3D data capture technology and collaborative technologies, at one planning yard. If successful, expand capability to all public-sector planning yards.
- Acquire both 3D data capture technology and collaborative technologies for all public-sector planning yards. If successful, consider applications beyond maintenance and modernization, such as shipbuilding, ship repair, and production activities.
- Immediately acquire laser scanning technology, with plans to adopt collaborative technologies within a certain timeframe (once a digital data warehouse of 3D models has accumulated to a valuable degree).
- Consider the policy revisions necessary for inclusion of 3D digital models into current Navy shipyard processes. Acquire technologies over time, for all Navy shipyard facilities.

D. RECOMMENDATIONS TO THE NAVY

Standardization of processes among public and private planning yards, and the industrial activities that build, repair, maintain, and modernize naval vessels is underway. The end goal of this standardization, in accordance with SHIPMAIN and various other incentives, is process improvement through data sharing. In one word, the overarching goal within the shipyard and planning yard community is *interoperability*.

Such a vision is necessary to move towards business practices that best utilize the technology available. It does not appear, however, that vision is the problem. Navy leadership is aware of what must occur to enable the establishment of a solid, IT-based infrastructure in the realm of industrial activity. There is positive momentum towards the achievement of this goal. However, the iterations of change tend to be slow, with many obstacles along the evolutionary path. As a result, the technological capability is

spiraling beyond the present day. Naval leadership must not have a static vision, but instead be visionaries, constantly reevaluating the end state of their goals. In this age of technology, the rate of advancements is not linear, but exponential. To stay competitive and improve processes using IT, one cannot afford to rest on a plateau.

It would benefit the Navy to begin a transition of change that would exploit the full capability research and development entities promise. If plans exist to create a common data repository for planning yards, its downstream industrial partners, and various stakeholders at all levels of the Chain of Command, then it should be designed to be as useful an asset as possible. A large-scale database enabling interoperability should include a capacity to store and manage both 2D and 3D data. By designing the database with the necessary tables and corresponding attributes for 3D, it would be ready for future growth into the 3D domain. A Database Management System (DBMS) must be capable of ensuring the integrity and availability of database information.

With all IT investments, cost tends to be front-loaded, and any benefit is only maximized with time. Risk is always present with IT investments. Data capturing technology, such as laser scanners, and the data sharing qualities of collaborative environments are not an exception to these rules. It is the responsibility of decision-makers to consider the amount of this risk in proportion to the potential value the technology may provide in time. The return would not be immediate, and current planning yard and shipyard processes would require modification. However, the value of 3D data capturing capability and collaboration is more than outwardly intuitive; it is backed by the analytical methodology presented in this research, and in respective ROK values.

Finally, an important consideration outside the scope of this thesis is the incredible number of applications this duo of technological assets could serve. First, repair efforts would be enhanced because geographical constraints would be removed. If a ship or submarine is underway or overseas, repair processes could be expedited through a collaborative interface with ship repair agencies, supply personnel, and other stakeholders, using 3D digital models of the damage captured by a laser scanner. On vessels where maximum utility of space is critical, such as amphibious assault ships

loaded out with Marine Corps equipment and aircraft, 3D models of storage areas would facilitate and improve planning. If new aircraft is introduced to the Fleet, such as the V-22 Osprey, with its unconventional design, 3D models of hangar decks could aid Air Department's layout.

3D modeling has potential applications in the area of ship damage control, in assisting in incidents of actual battle damage, or fire, flooding, or other ship emergency. Similarly, these models would be beneficial in training commands, from boot camp on. Modeling would be advantageous for shipbuilding, and configuration control of ships built within the same class. There are a myriad of possibilities for this technology that make up for its current limitations. The scope is as far as imagination and funding provides. In the interim, these technological assets could be applied as an initial step towards a more enduring strategy.

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